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EVALUATION OF SAGMI AND HAST AIRLOADS AT THE F-4C CENTERLINE CARRIAGE POSITION FOR SUBSONIC AND TRANSONIC MACH NUMBERS

Richard W. Butler
ARO, Inc.

March 1972

PROPULSION WIND TUNNEL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

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FOREWORD

The work reported herein was sponsored by the Air Force Armament Laboratory (AFATL/DLGC/Mr. C. Mathews), Armament Development and Test Center, Air Force Systems Command (AFSC), under Program Element 62602F.

The test results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted January 17 and 18, 1972, under ARO Project No. PC0201. The manuscript was submitted for publication on March 2, 1972.

This technical report has been reviewed and is approved.

George F. Garey
Lt Colonel, USAF
AF Representative, PWT
Directorate of Test

Frank J. Passarello
Colonel, USAF
Acting Director
Directorate of Test

ABSTRACT

A wind tunnel investigation was conducted to determine the airloads on the SAGMI and HAST vehicles at the F-4C centerline carriage position. In the process of obtaining these loads, a limited amount of sting interference data on the SAGMI vehicle was obtained. Force and moment data were recorded at Mach numbers from 0.50 to 1.20 for angles of attack from -4 to 12 deg and angles of sideslip from -8 to 8 deg. Test results revealed that normal-force airloads experienced on the SAGMI and HAST vehicles while in the F-4C centerline carriage position at large angles of attack (8 to 12 deg) were orders of magnitude smaller than free-stream loads obtained on similarly shaped bodies. The addition of a dummy sting support at the base of the SAGMI vehicle resulted in a decrease in both normal-force and axial-force coefficients, with an increase in pitching-moment coefficient, at all subsonic test conditions.

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NOMENCLATURE

b	Reference dimension, SAGMI 15.367 in., HAST 15.000 in. (model length)
C_A	Axial-force coefficient, axial force/$q_\infty S$
C_ℓ	Rolling-moment coefficient, rolling moment/$q_\infty Sb$
C_m	Pitching-moment coefficient, pitching moment/$q_\infty Sb$
C_N	Normal-force coefficient, normal force/$q_\infty S$
C_n	Yawing-moment coefficient, yawing moment/$q_\infty Sb$
C_Y	Side-force coefficient, side force/$q_\infty S$
M_∞	Free-stream Mach number
q_∞	Free-stream dynamic pressure, lb/ft^2
S	Reference area, SAGMI and HAST = 0.00518 ft^2 (model cross sectional area)
α_m	Fuselage angle of attack, deg
β	Fuselage angle of sideslip, deg

SECTION I
INTRODUCTION

One step in the evolutionary process of qualifying an external store for aircraft carriage and separation is the determination of the inflight carriage loads. A comparison of these loads with the load carrying capabilities of the pylon is a prerequisite for initial flight testing. These loads are often obtained by examining load coefficients generated by similar store shapes in a similar flow field. Because of the canards and rather large wing areas associated with the Supersonic Air-to-Ground Missile (SAGMI) and High Altitude Supersonic Target (HAST) vehicles, it becomes difficult to estimate their carriage loads based on some of the more conventional weapons. To this end, an experimental study was conducted in the Aerodynamic Wind Tunnel (4T) of the Propulsion Wind Tunnel Facility (PWT).

The test was conducted to determine the inflight aerodynamic loads on the SAGMI and HAST vehicles at the F-4C centerline carriage position. With the technique used in supporting the store, it also became feasible to obtain a limited amount of sting-support interference data.

Force and moment data were obtained at Mach numbers from 0.50 to 1.20 for angles of attack from -4 to 12 deg and for angles of sideslip from -8 to 8 deg.

SECTION II
APPARATUS

2.1 TEST FACILITY

Tunnel 4T is a closed-loop, continuous flow, variable density tunnel in which the Mach number can be varied from 0.1 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 300 to 3700 psfa. The test section is 4 ft square and 12.5 ft long with perforated, variable porosity (0.5- to 10-percent-open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section. A more thorough description of the tunnel is given in Ref. 1. A schematic showing the test section details and the location of the model in the tunnel is shown in Fig. 1, Appendix.

2.2 TEST ARTICLE

The wind tunnel models used in this test were 0.075-scale models of the F-4C aircraft, SAGMI vehicle, and HAST vehicle. Sketches showing basic dimensions of the models are shown in Figs. 2 and 3. A photograph of a typical model installation in Tunnel 4T is shown in Fig. 4.

The SAGMI and HAST vehicles were located on the F-4C centerline pylon shown in Fig. 5. All other pylon stations were clean. The internal balance used in each store was supported through the centerline pylon, alleviating the conventional sting support at the base of each model. In an attempt to ascertain how the altered flow field induced by a conventional sting-support system would affect the force and moment data, provisions

were made for installing a dummy sting-support system. Figure 6 shows a sketch of the dummy sting-support system. With the sting attached to the F-4C fuselage undersurface and aligned with the store centerline, a gap of 0.030 in. existed between the store base and the sting. A photograph showing the dummy sting installed with the HAST vehicle is shown in Fig. 7.

2.3 INSTRUMENTATION

The aerodynamic loads on the model were measured with a six-component, internal strain-gage balance. Total forces and moments were measured directly from the balance sensing components.

Aircraft angle of attack and angle of sideslip were calculated and set utilizing computer-controlled pitch and roll mechanisms. An absolute-angle transducer located in the F-4C model gave the true inclination of the fuselage centerline at any roll angle.

SECTION III
PROCEDURE

3.1 GENERAL

The normal testing procedure was to establish the tunnel Mach number and Reynolds number and initiate the automated pitch and roll routine. The computer would then automatically position the model through a predetermined sequence of angle-of-attack and angle-of-sideslip combinations.

The tunnel dynamic pressure was maintained at a constant value of 500 psf for all Mach numbers.

3.2 PRECISION OF MEASUREMENT

The tunnel 4T Mach number calibration shows that the variation in Mach number in the test section region occupied by the model was no greater than ±0.005.

The uncertainties in setting tunnel total pressure, fuselage centerline angle of attack, and sting roll angle were no greater than ±10 psf, ±0.1 deg, and ±1.0 deg, respectively.

Uncertainties in the measured force and moment coefficients were calculated based on inaccuracies in balance measurements. The uncertainties are based on a 95-percent confidence level and are presented below.

ΔC_N	ΔC_Y	ΔC_A	ΔC_ℓ	ΔC_m	ΔC_n
±0.018	±0.013	±0.030	±0.0006	±0.003	±0.004

SECTION IV
RESULTS AND DISCUSSION

4.1 GENERAL

The primary requirement for this test was to define airloads on the SAGMI and HAST vehicles when carried at the F-4C fuselage centerline. In accomplishing this it became apparent that, because of the nature of the model suspension, an opportunity existed for obtaining much-needed transonic sting interference data. These data were obtained and are presented with the airloads data.

4.2 SAGMI AIRLOADS

Airload coefficients for the SAGMI vehicle are presented in Figs. 8 and 9 as functions of angle of attack and angle of sideslip, respectively. The data were obtained over a Mach number range from 0.50 to 1.20. Sting interference data are also presented in these figures. Inflight carriage loads and moments may be readily obtained from each of these plots by using the proper reference dimensions as defined in the nomenclature. The magnitude of the loads is astonishingly small compared to free-stream loads data obtained from similarly shaped bodies. At 12-deg angle of attack one would expect the free-stream normal-force coefficient to be an order of magnitude greater than those measured on the SAGMI model in the F-4C environment.

Another area of interest in Figs. 8 and 9 is the apparent effectiveness of the SAGMI canards as depicted in the C_m and C_N curves. At all Mach numbers and angles of attack, they appear to produce a negative lift indicated by the rearward position of the center of pressure. This would indicate an aircraft-induced downwash in the region of the canards even at the highest fuselage angle of attack.

A considerable amount of effort was expended attempting to resolve the nonzero side-force coefficients experienced with the model at zero angle of sideslip, Fig. 8. A data uncertainties band was defined based on balance precision and ability in setting fuselage angle. The uncertainties band covered a ΔC_Y of ± 0.044. Attempting to locate some physical phenomenon which might induce a shift in C_Y greater than the data uncertainties led to four possible culprits: a balance zero shift, a wind tunnel-induced crossflow, an asymmetric-induced flow field from the parent aircraft, and misalignment of the SAGMI vertical stabilizing fins. Balance zero shifts were insignificant below Mach number 1.05. At Mach numbers 1.05 and 1.20, a C_Y shift of 0.09 occurred. The possibility of the side force originating from misalignment of the model vertical stabilizing fins was discounted following detailed checks of fin alignment. The remaining culprits would be the fuselage or tunnel-induced crossflow. It is interesting to note that if all the C_Y shift is assumed to result from the above crossflow, the worst case (occurring at Mach number 0.95) would only amount to 0.3 deg flow angularity. This is typical of measurements of empty tunnel flow angularities made in Tunnel 4T.

Care should be exercised in comparing the side-force and rolling-moment coefficients obtained during pitch runs (Fig. 8) and yaw runs (Fig. 9), as they have been plotted to different scale factors.

4.3 HAST AIRLOADS

Airloads data obtained on the HAST vehicle are presented in Figs. 10 and 11 for varying angle of attack and angle of sideslip, respectively. This presentation of data is identical to the SAGMI data with the exception that sting interference effects are not included. As in the SAGMI data, the HAST normal-force airloads experienced in the carriage position are much less than corresponding free-stream data (Ref. 2). The HAST canards also experienced a negative force resulting in a rearward center of pressure at all angles of attack.

The nonzero side-force coefficients occurring with the model at zero angle of sideslip fall within the HAST data uncertainty band of ±0.05.

4.4 STING INTERFERENCE

Flow separation from the body at the model base creates a region of low-energy air immediately behind the base. Because of viscous mixing, the external free stream aspirates this region and lowers its pressure. This in turn directs the free stream inward with an accompanying increase in velocity. Farther downstream, the free stream must be turned to become horizontal again resulting in an increase in pressure. A steady-state base pressure is established when the two opposing effects are in equilibrium. The model wake region established from the above phenomenon normally possesses a pressure less than free-stream static pressure, thereby resulting in a positive axial-force contribution. By placing a sting at the rear of the model, the wake contraction is reduced, thereby resulting in a base pressure increase and a corresponding reduction of axial force. Figures 8 and 9 provide an experimental verification of these effects. At all Mach numbers, the axial-force coefficient is reduced with the presence of the sting.

The sting also has effects on the body pressure ahead of the model base that are similar to the sting effects on the base pressure. These effects are transmitted through the body boundary layer and result in a more positive body pressure gradient. The reduced normal-force coefficients in Figs. 8 and 9 with the presence of a sting indicate that the model upper surface pressures are increased by this feeding upstream of a positive pressure.

The apparent side-force discrepancy observed in the presence of a sting at Mach numbers 0.50, 1.05, and 1.20 in Fig. 8 is attributed to an observed shift in the balance zero reading on the side-force gage when testing the SAGMI without the dummy sting.

SECTION V
CONCLUSIONS

As a result of the test reported herein on the SAGMI and HAST vehicles in the F-4C centerline carriage position, the following summarizing statements are made:

1. Normal-force airloads experienced on the SAGMI and HAST vehicles at large angles of attack (8 to 12 deg) were orders of magnitude smaller than free-stream loads obtained on similarly shaped bodies.

2. The flow field of the F-4C aircraft resulted in a center-of-pressure location on the SAGMI and HAST very far aft corresponding to a downwash on the canards.

3. The addition of a dummy sting support at the base of the SAGMI vehicle resulted in a decrease in both normal-force and axial-force coefficients, with an increase in pitching-moment coefficient, at all subsonic test conditions.

REFERENCES

1. Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

2. Carman, J. B. "Static Stability and Inlet Characteristics of the HAST Missile at Transonic Mach Numbers." AEDC-TR-71-178 (AD887776L), September 1971.

APPENDIX
ILLUSTRATIONS

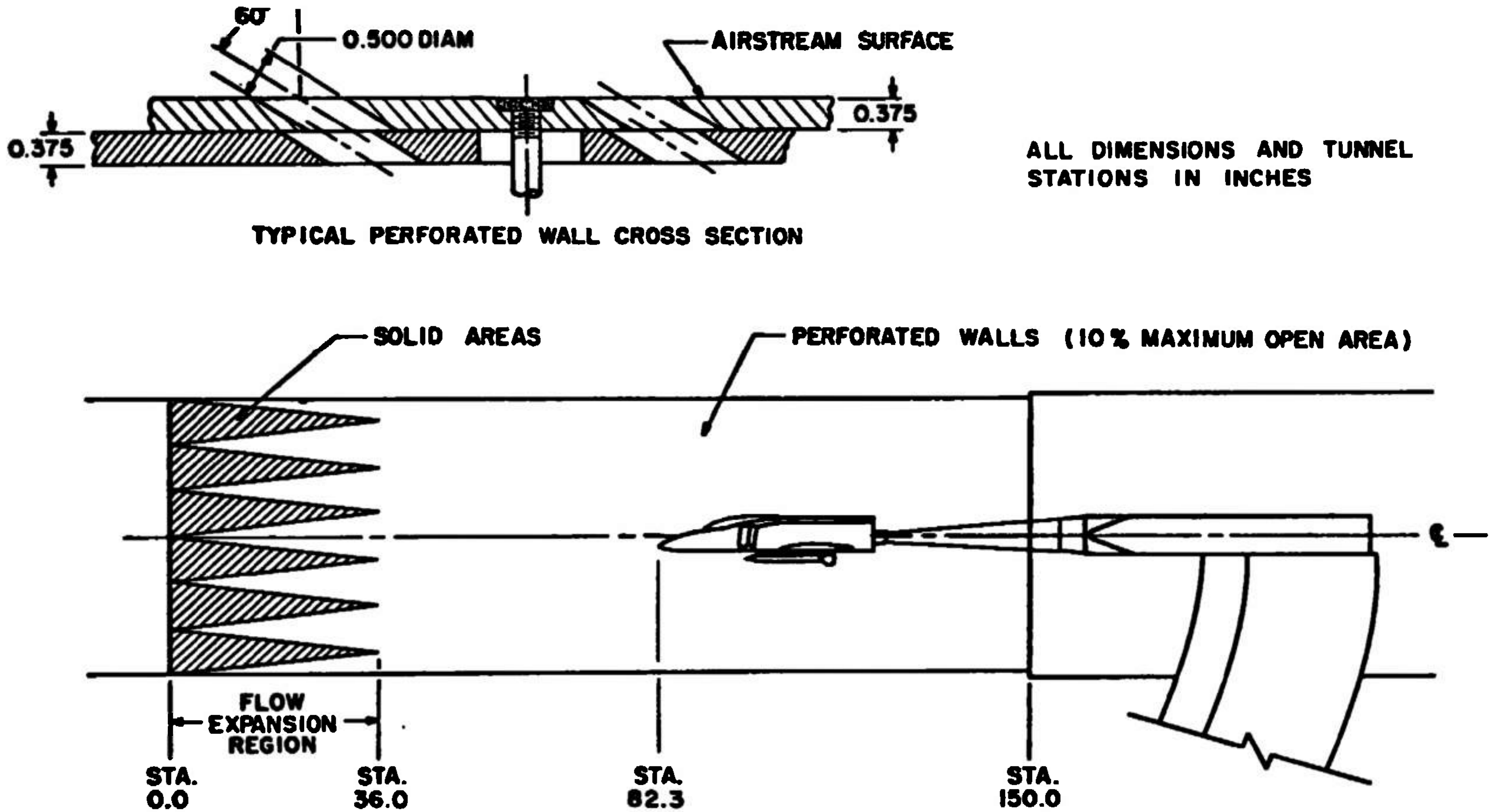


Fig. 1 Schematic of the Tunnel Test Section Showing Model Location

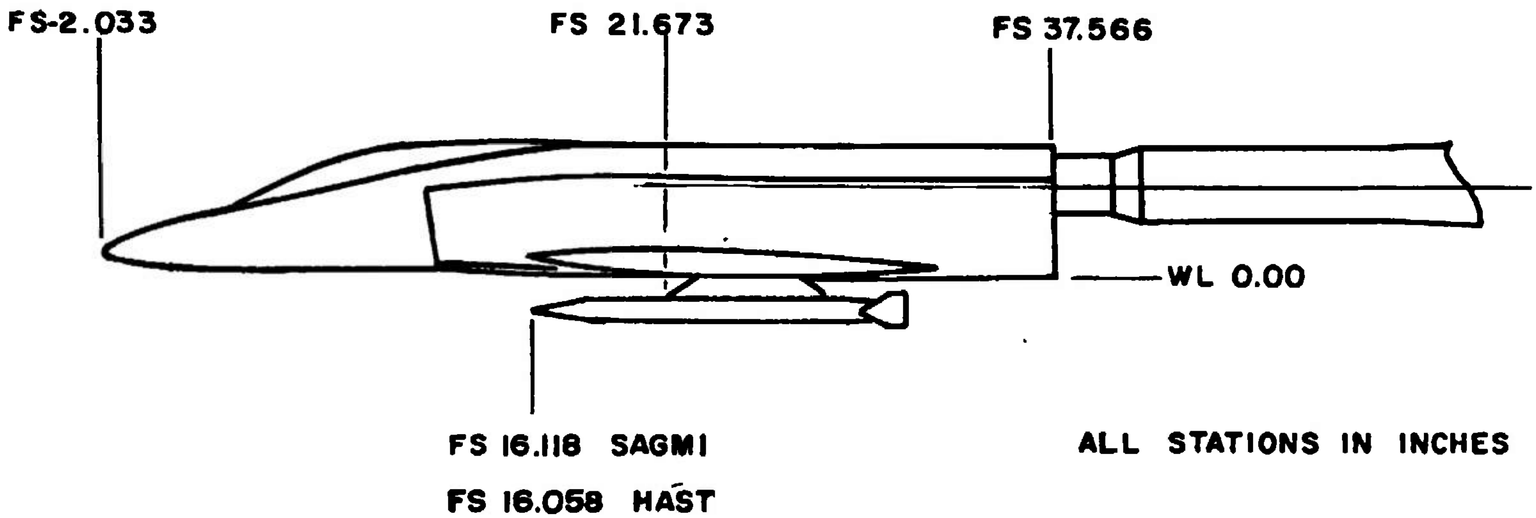
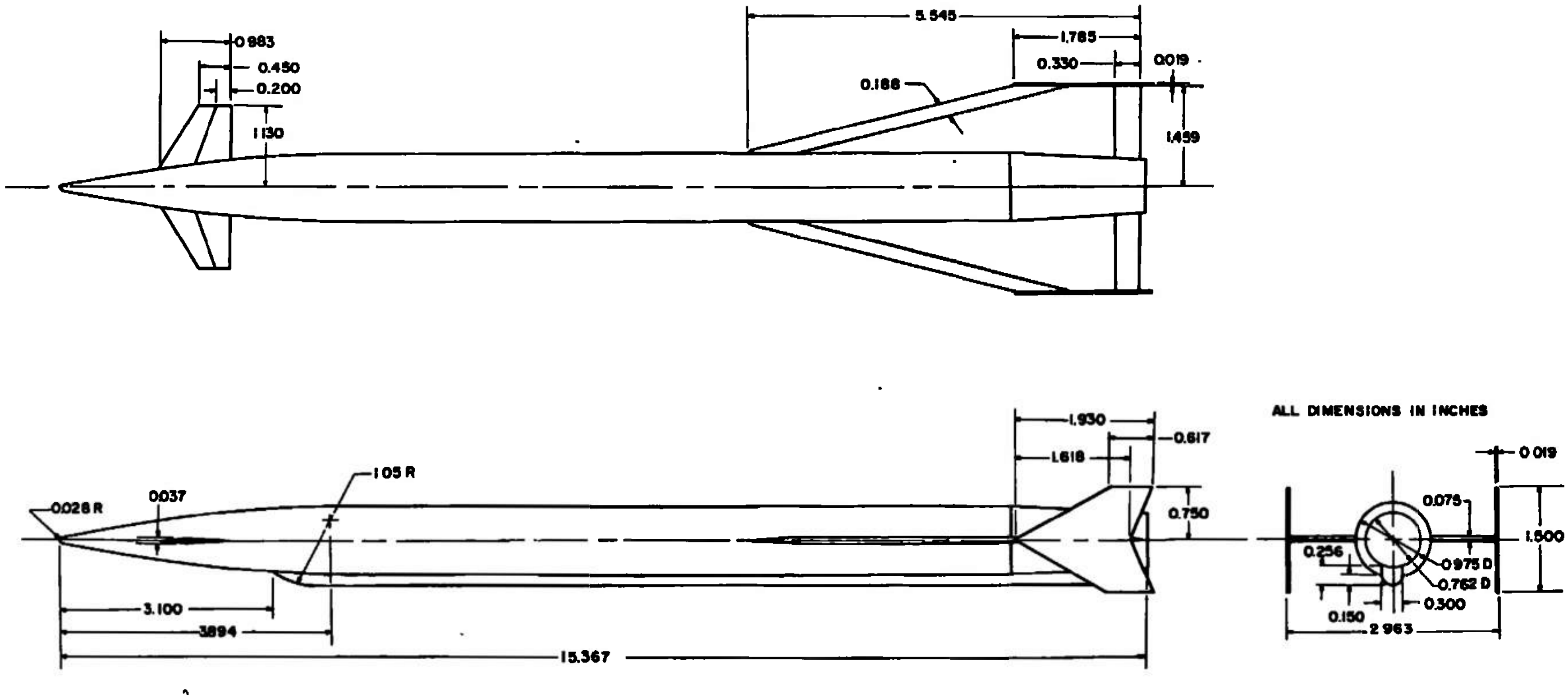
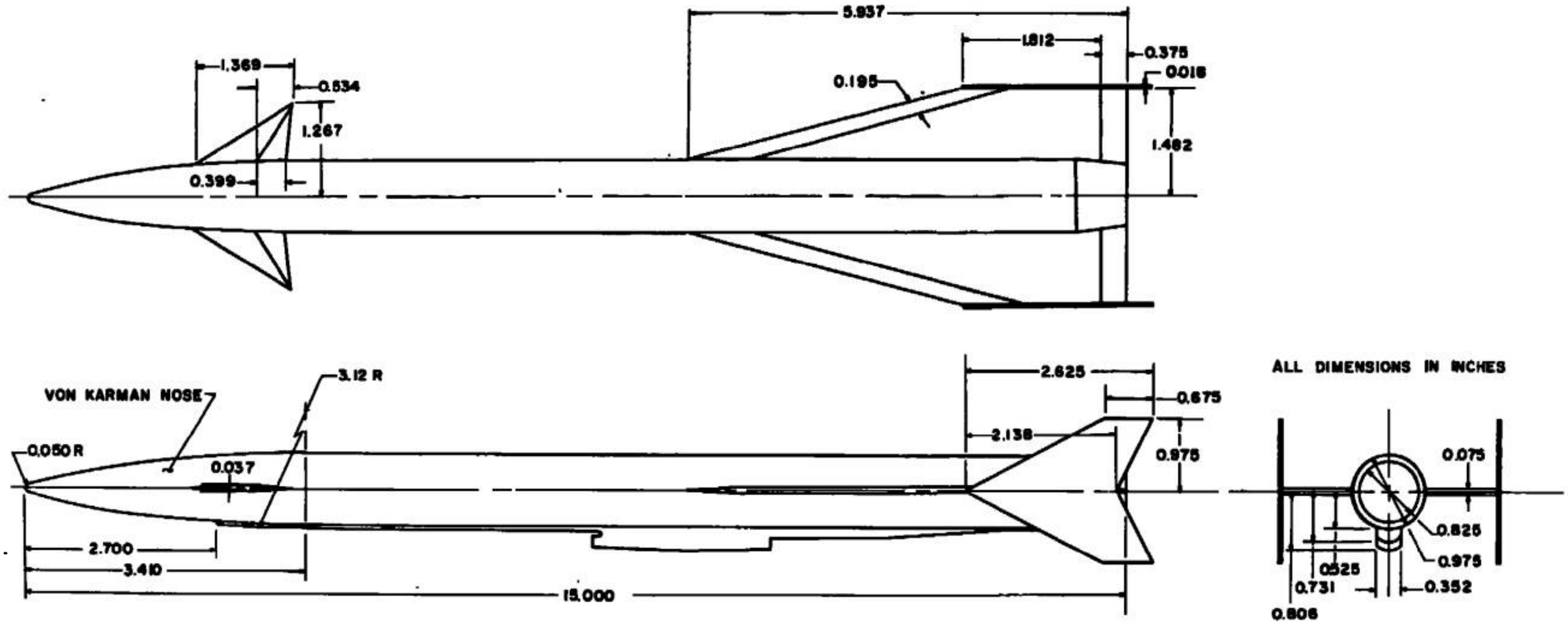


Fig. 2 Dimensional Sketch of the F-4C Parent Model



a. SAGMI
Fig. 3 Dimensional Sketch of the SAGMI and HAST Vehicles



b. HAST
Fig. 3 Concluded

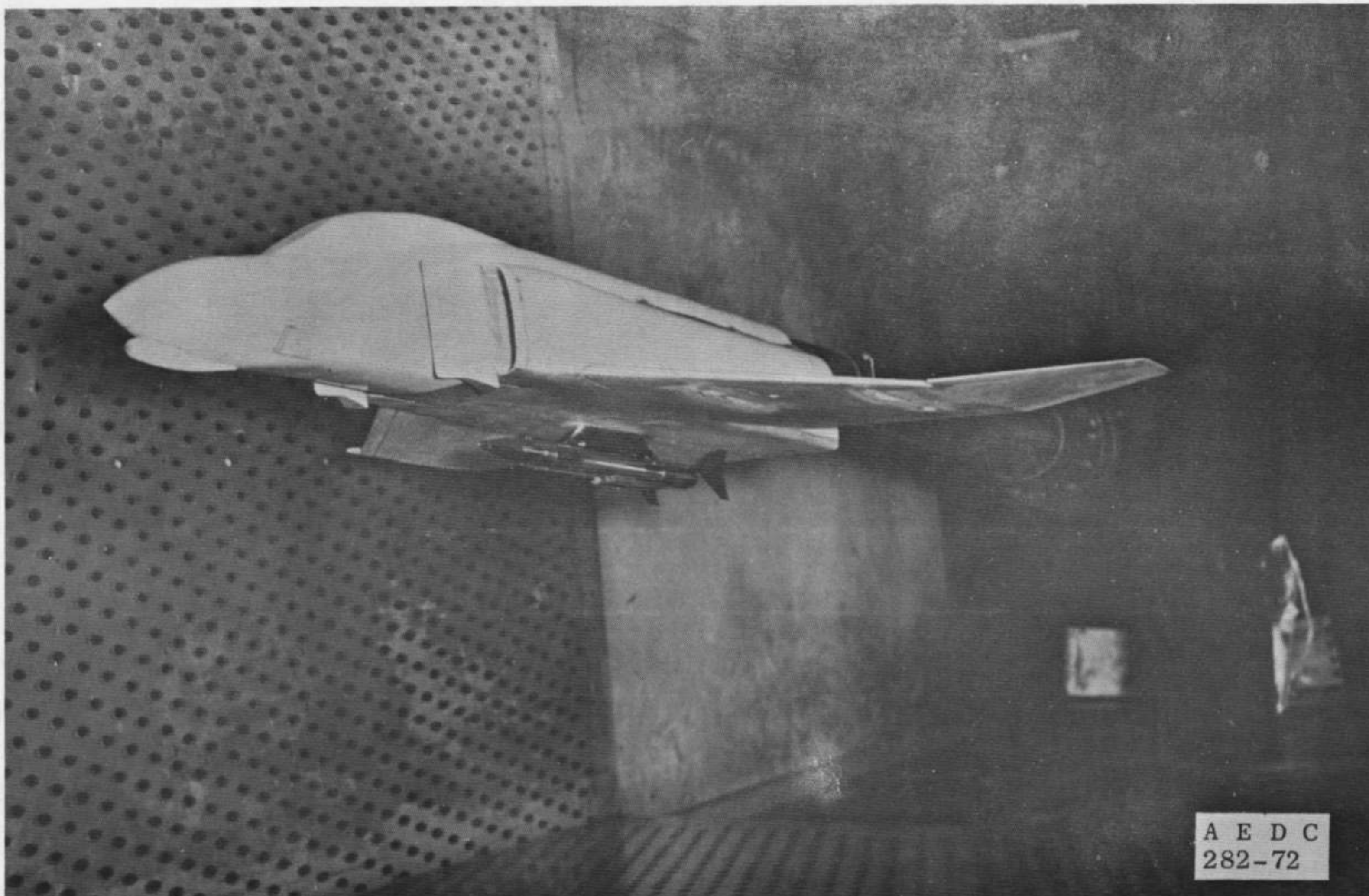
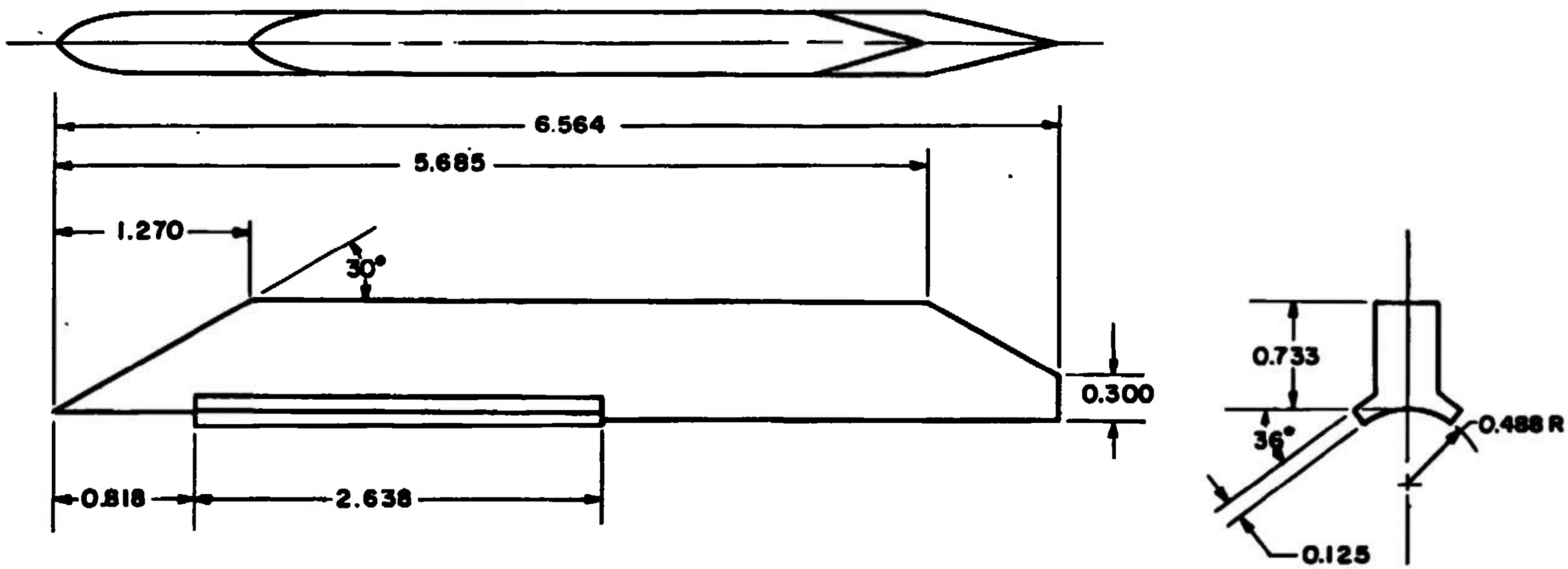


Fig. 4 Tunnel Installation Photograph Showing the F-4C Parent Model with HAST Vehicle



ALL DIMENSIONS IN INCHES

Fig. 5 Dimensional Sketch of the F-4C Centerline Pylon

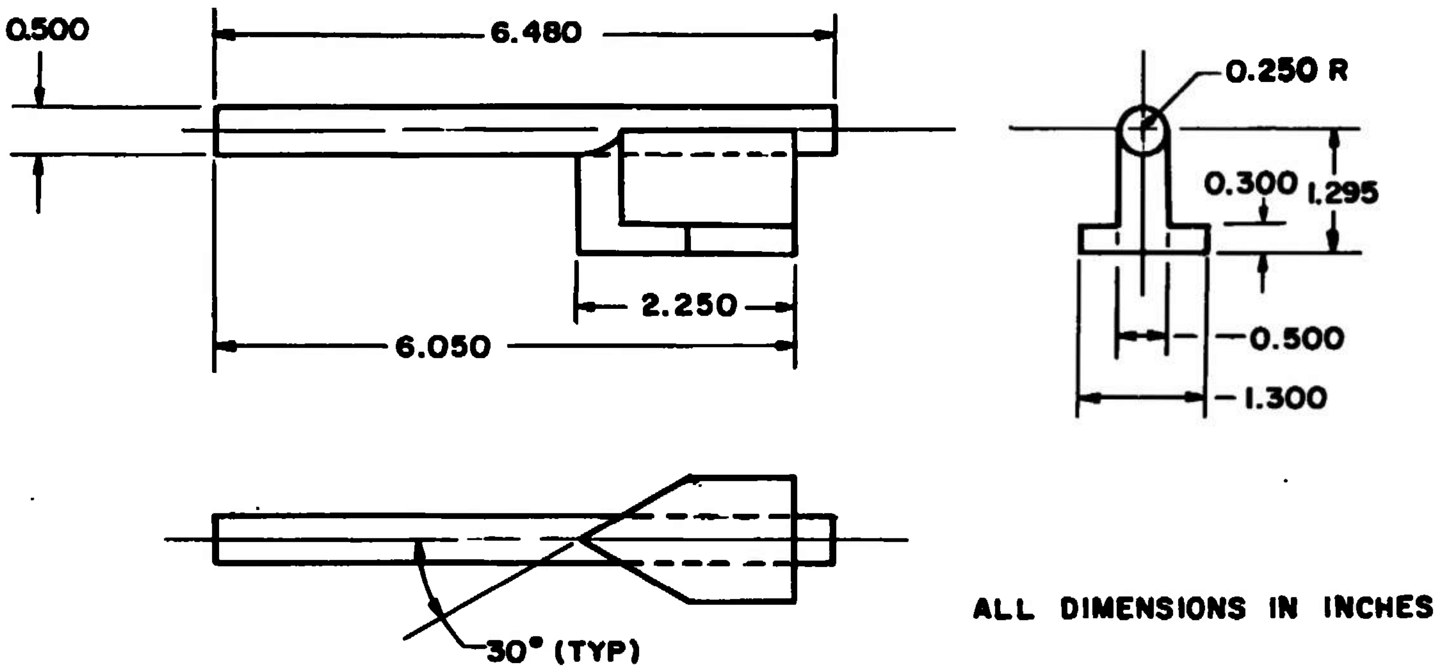


Fig. 6 Dimensional Sketch of the Dummy Sting-Support System

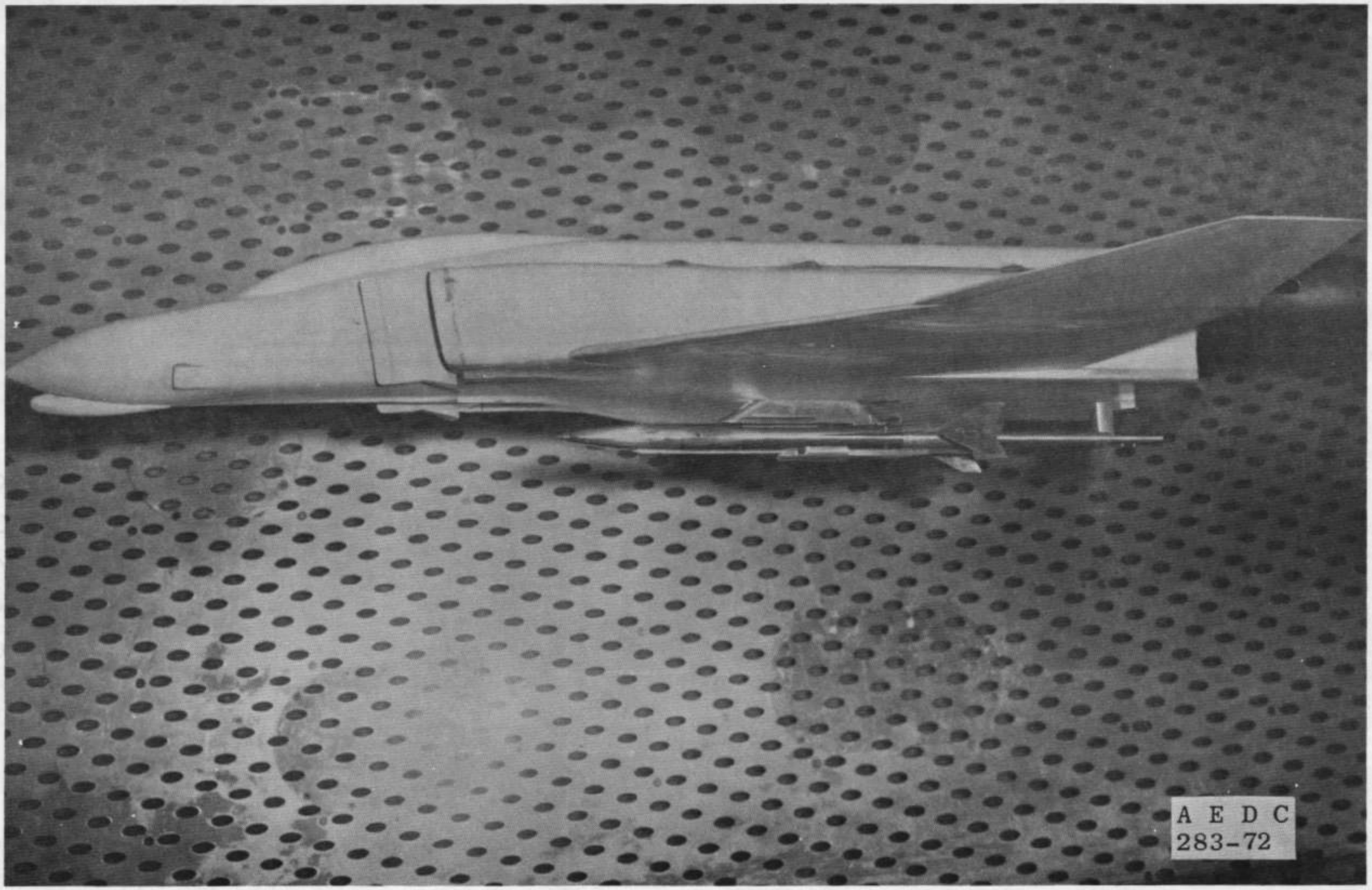
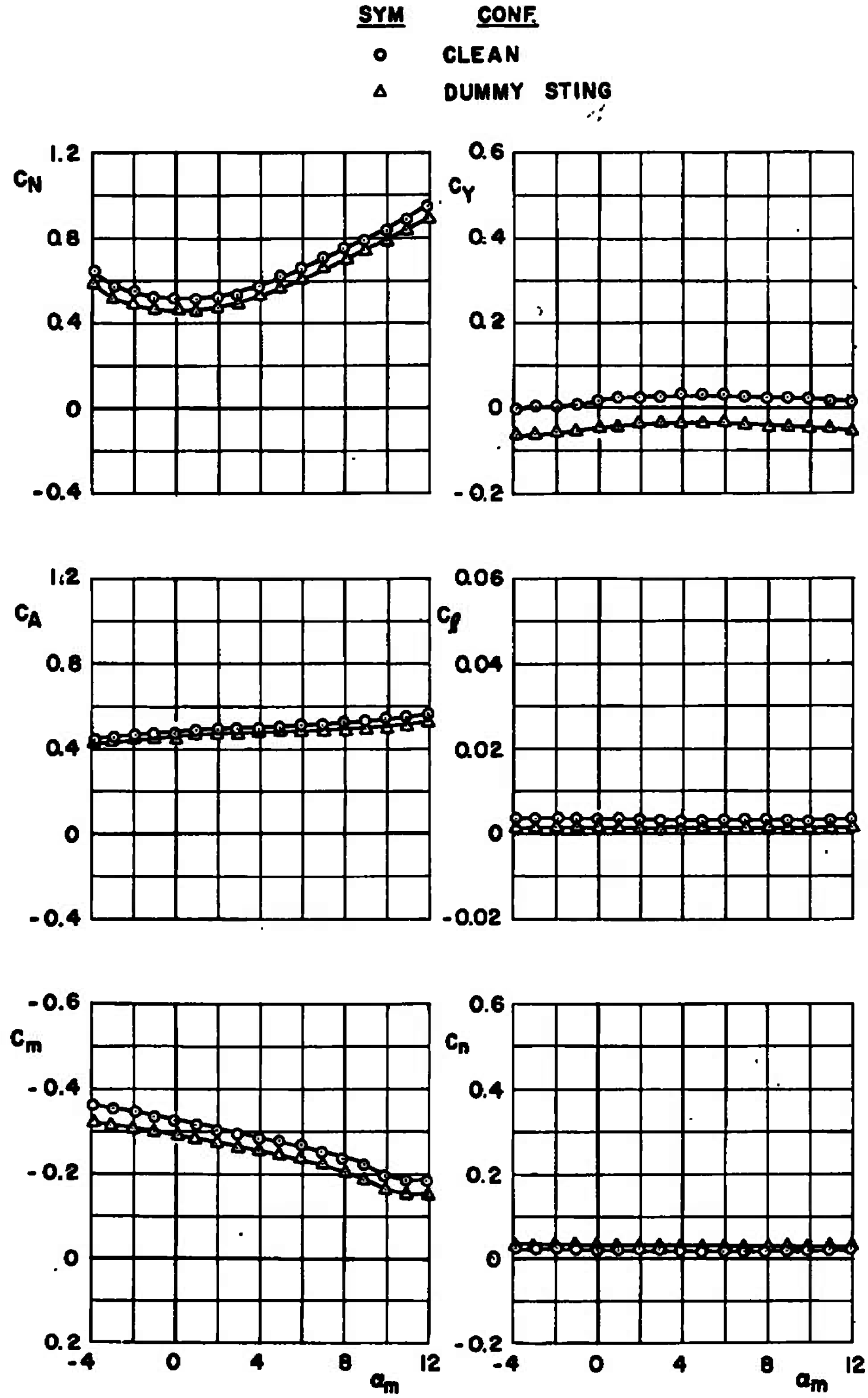
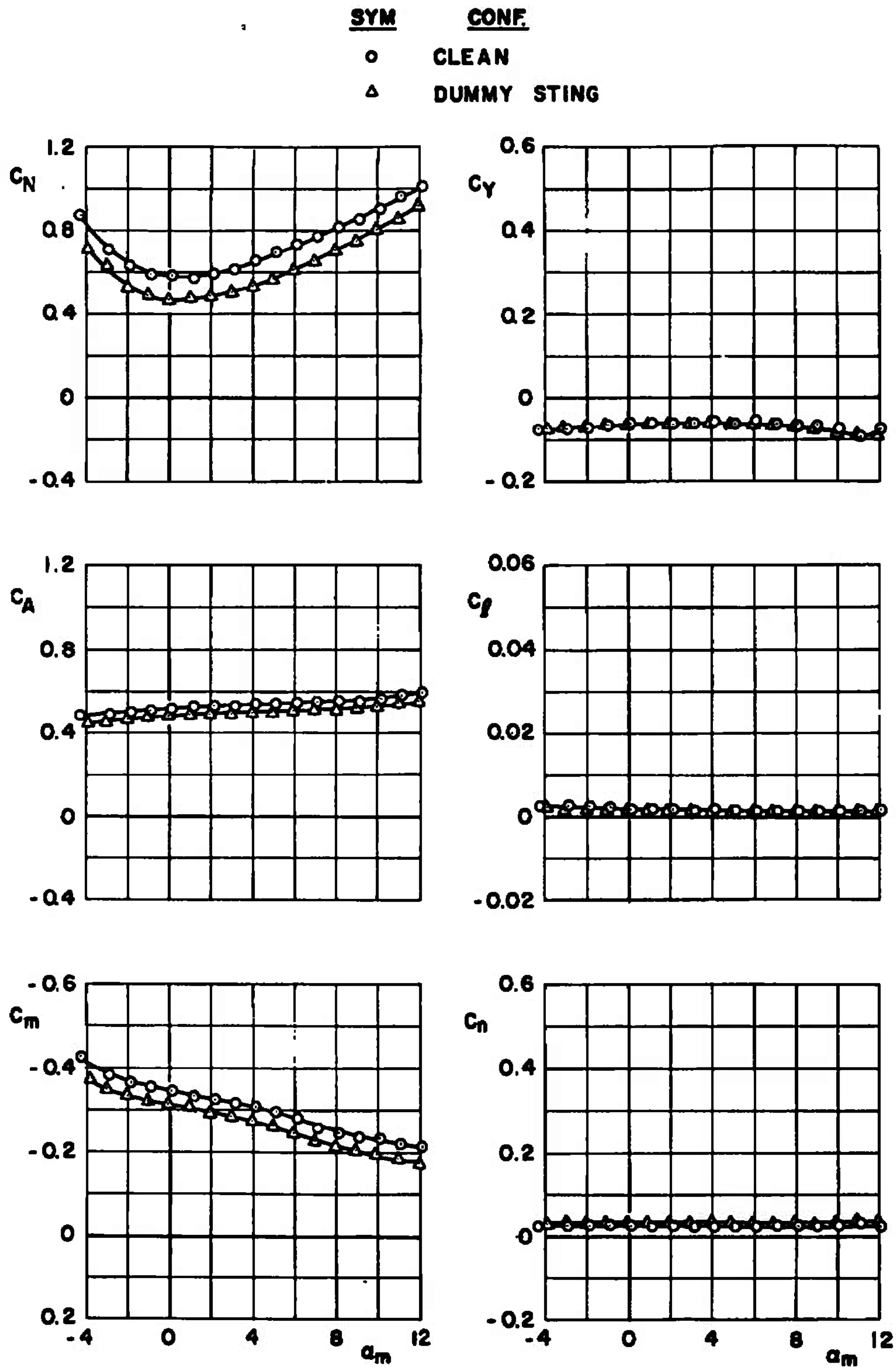


Fig. 7 Photograph Showing Installation of the Dummy Sting Support on the F-4C Aircraft Model

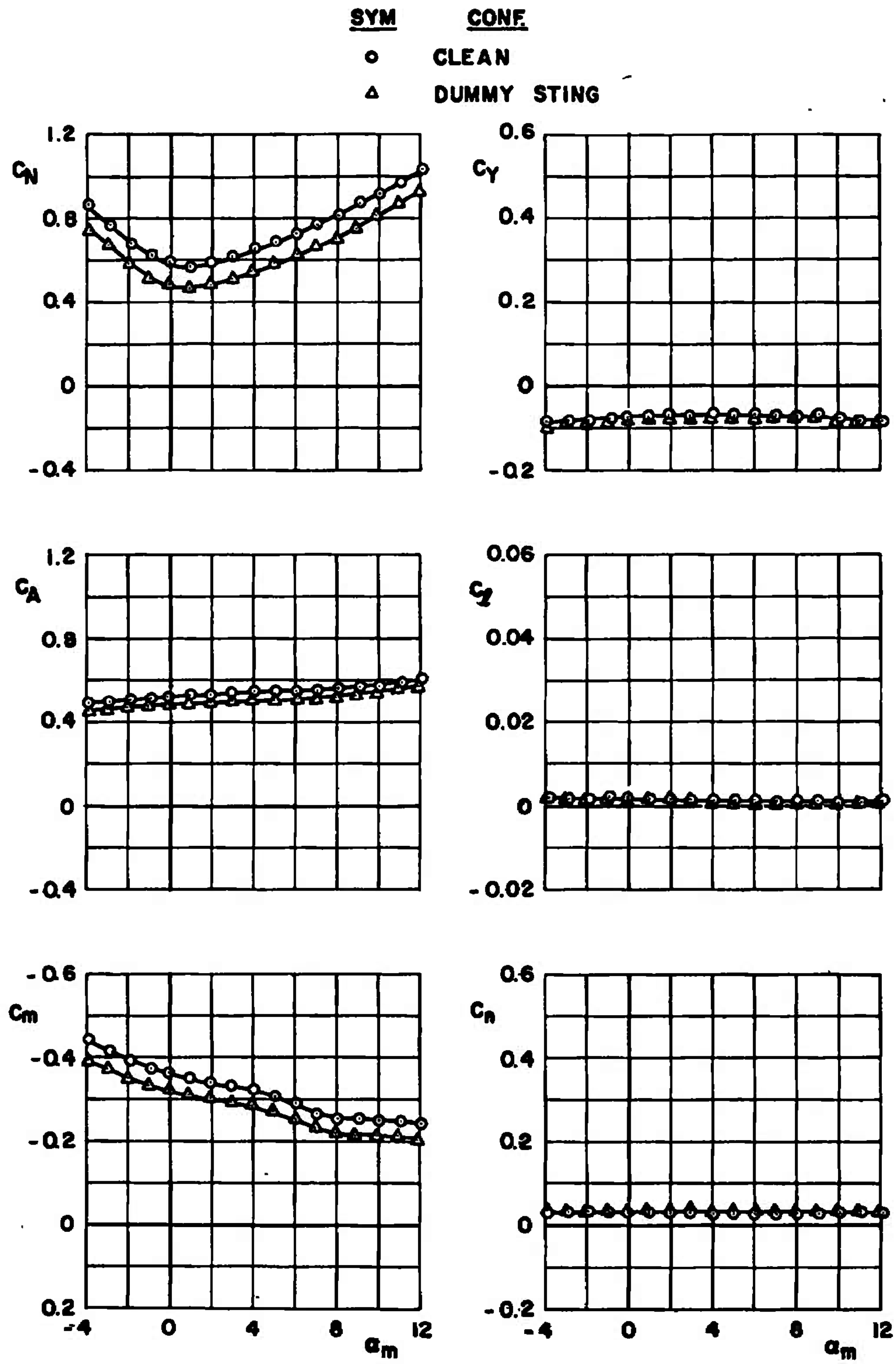


a. $M_\infty = 0.50$

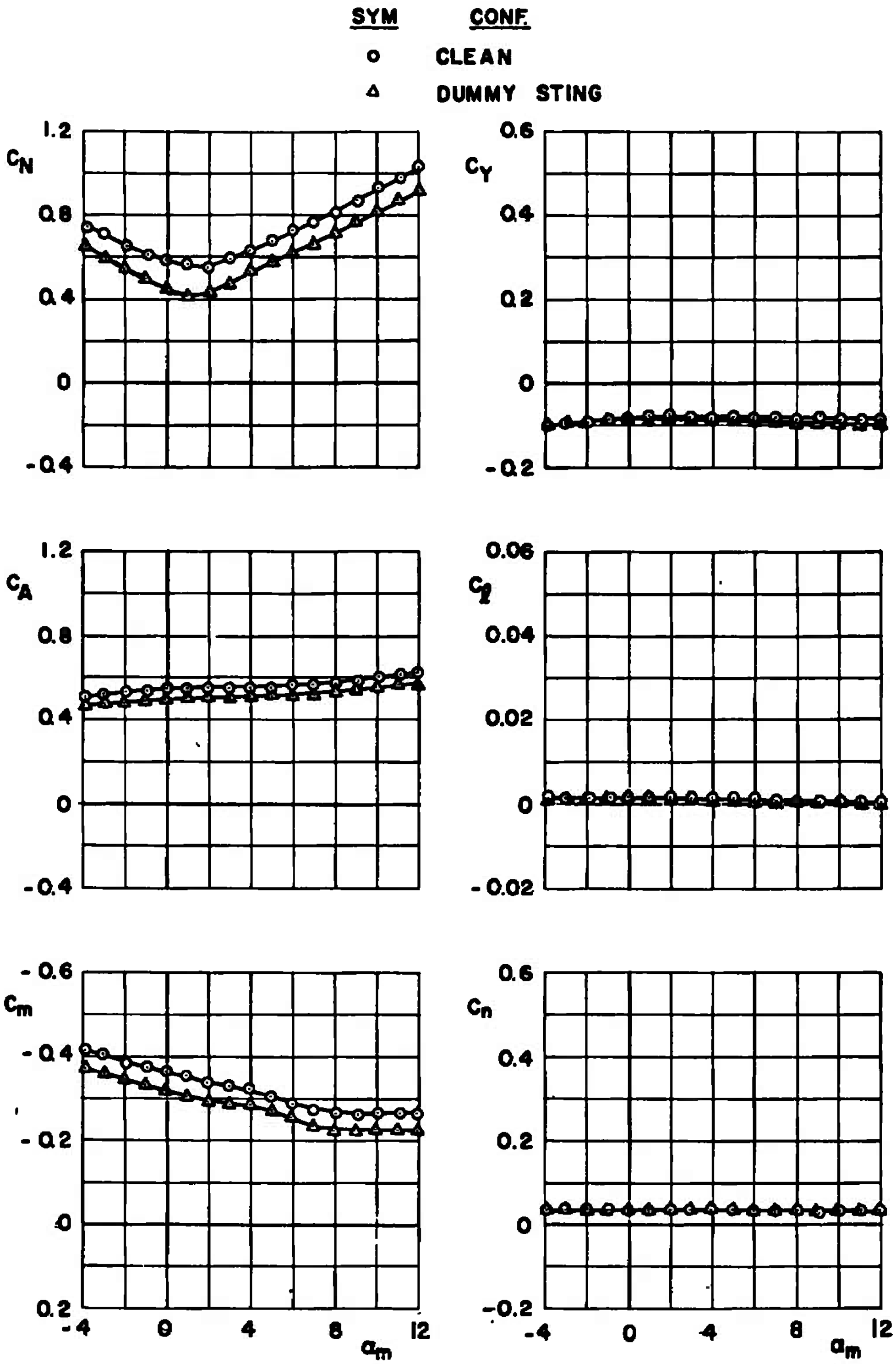
Fig. 8 SAGMI Aerodynamic Coefficients as a Function of Angle of Attack, $\beta = 0$



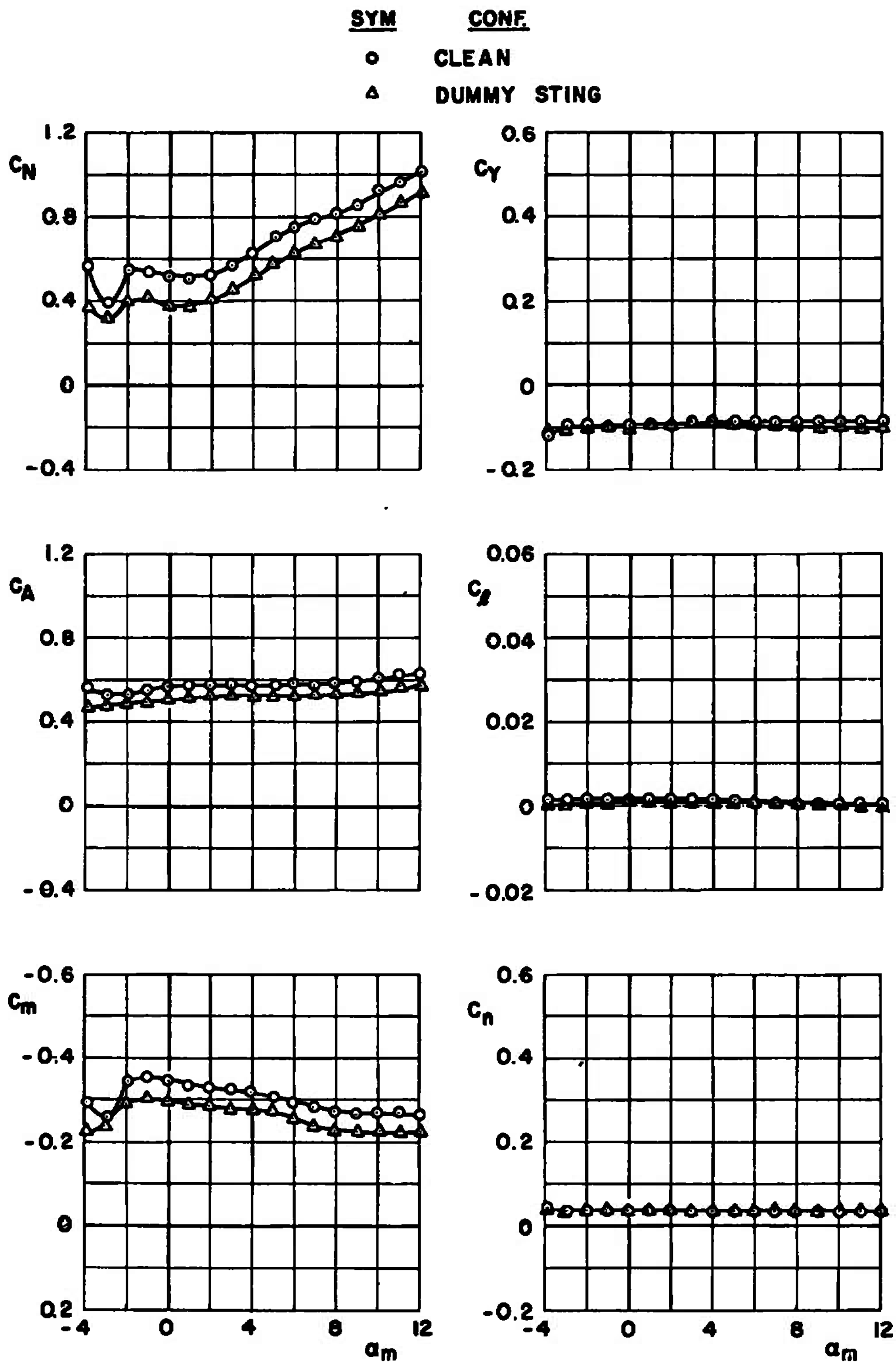
b. $M_\infty = 0.70$
Fig. 8 Continued



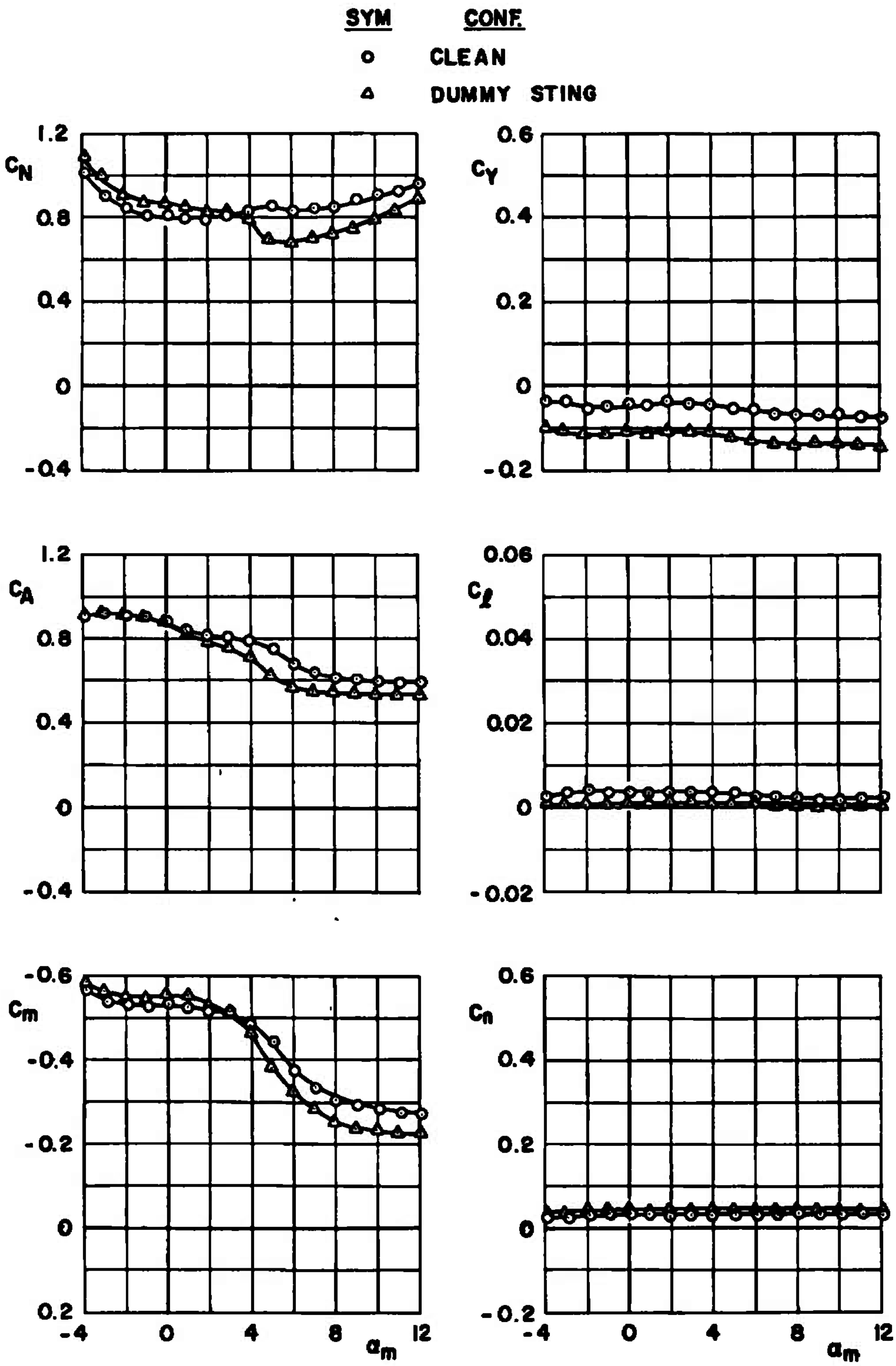
c. $M_\infty = 0.80$
Fig. 8 Continued



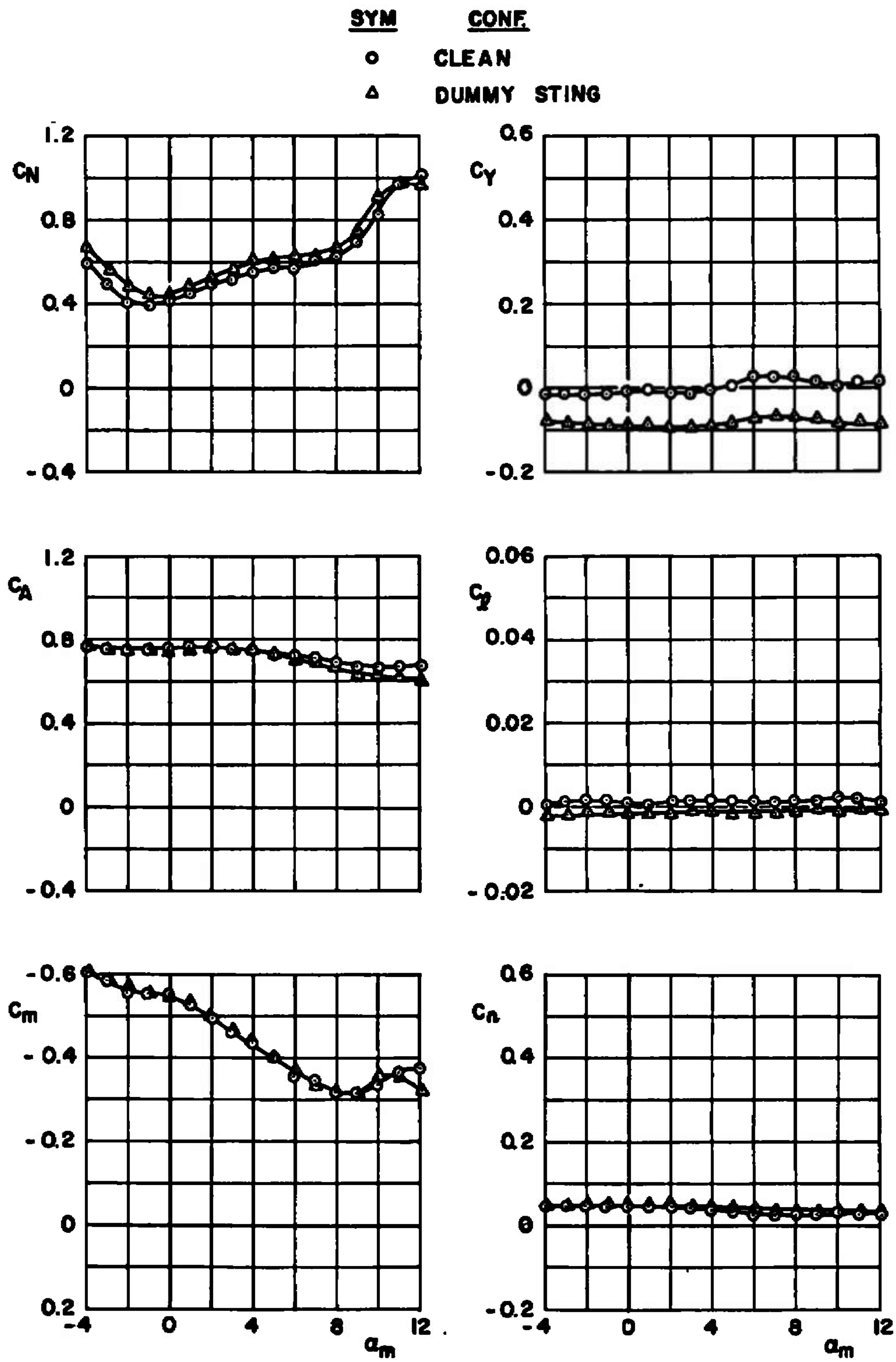
d. $M_\infty = 0.90$
Fig. 8 Continued



e. $M_\infty = 0.95$
Fig. 8 Continued

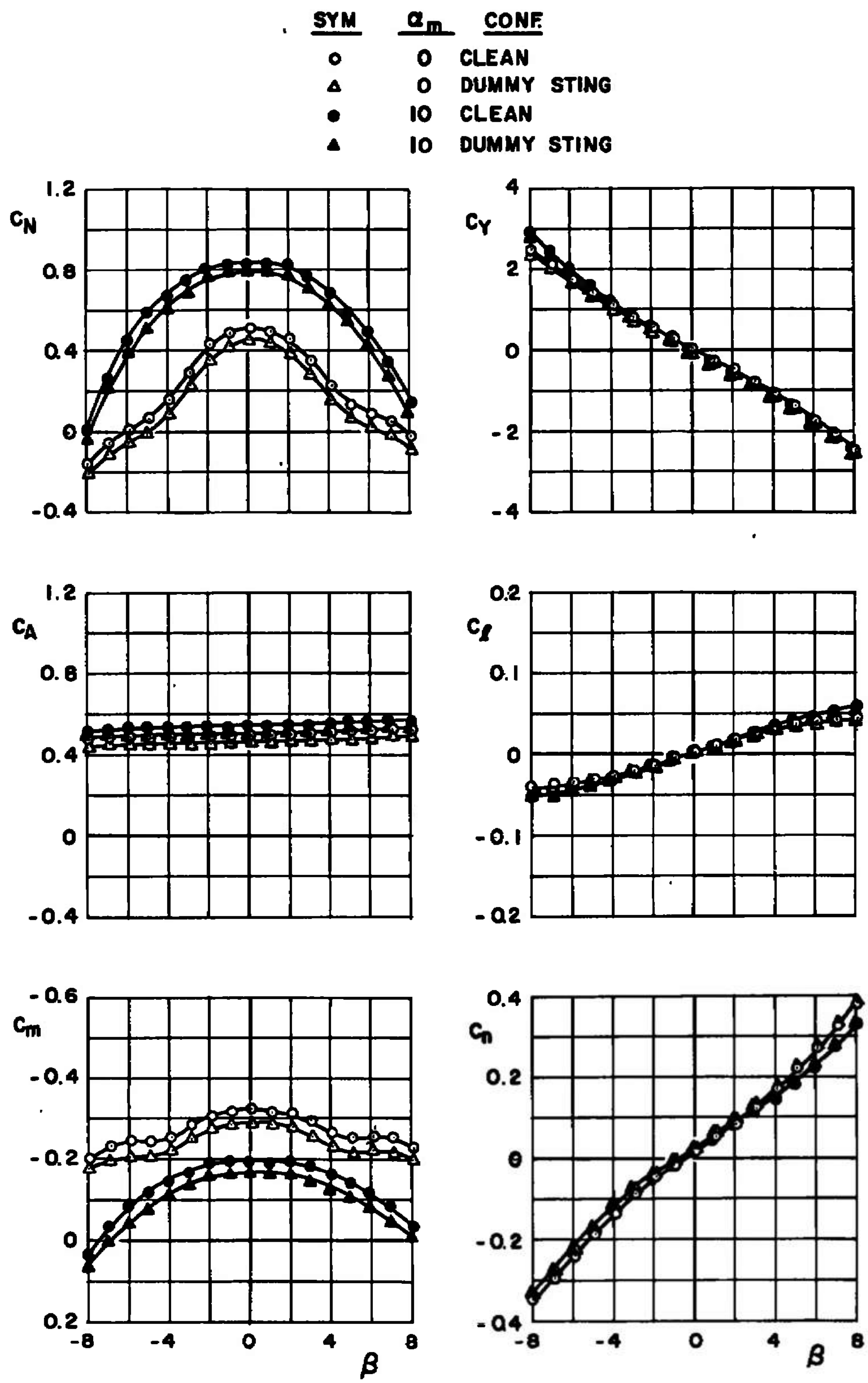


f. $M_\infty = 1.05$
Fig. 8 Continued



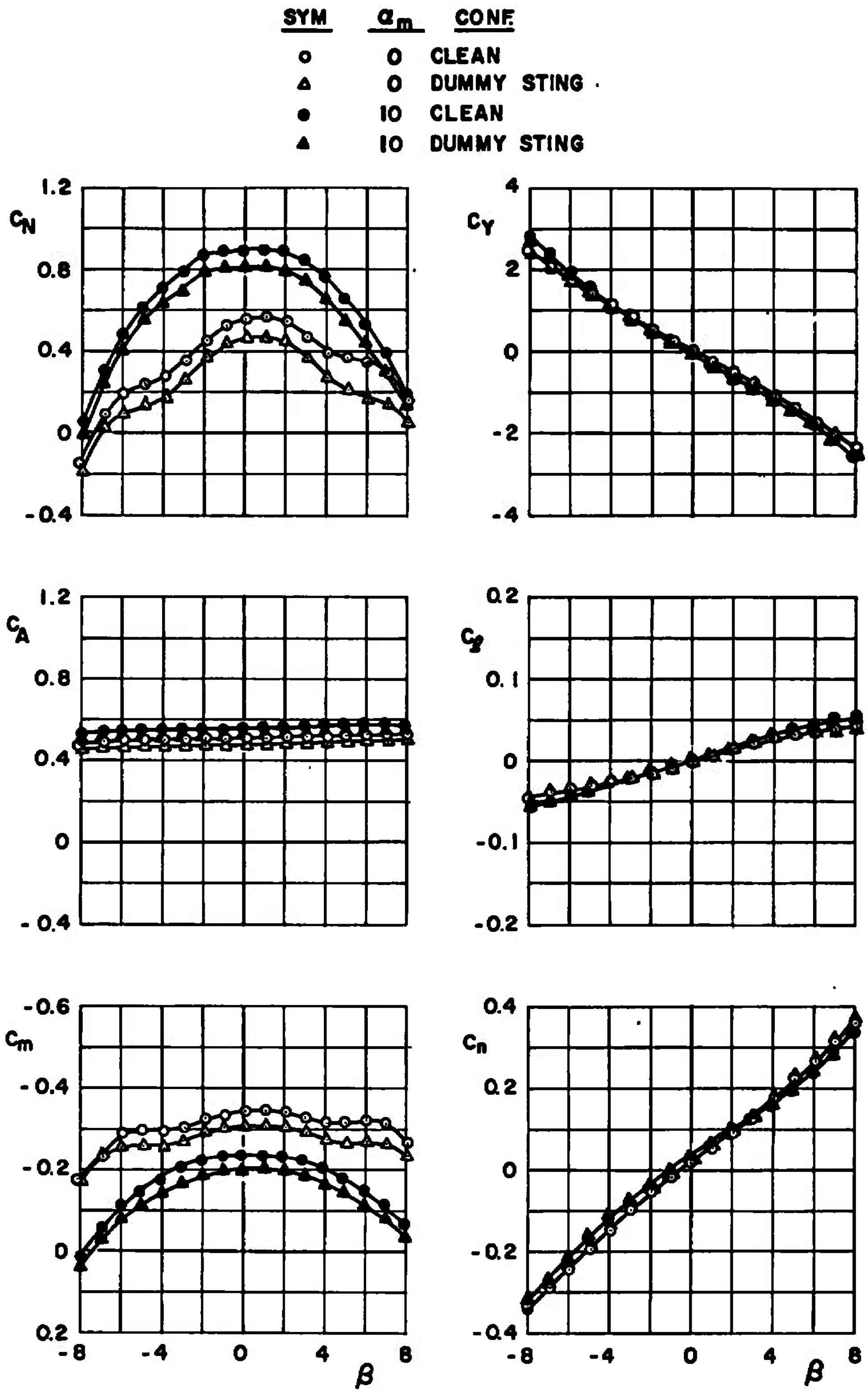
g. $M_\infty = 1.20$

Fig. 8 Concluded

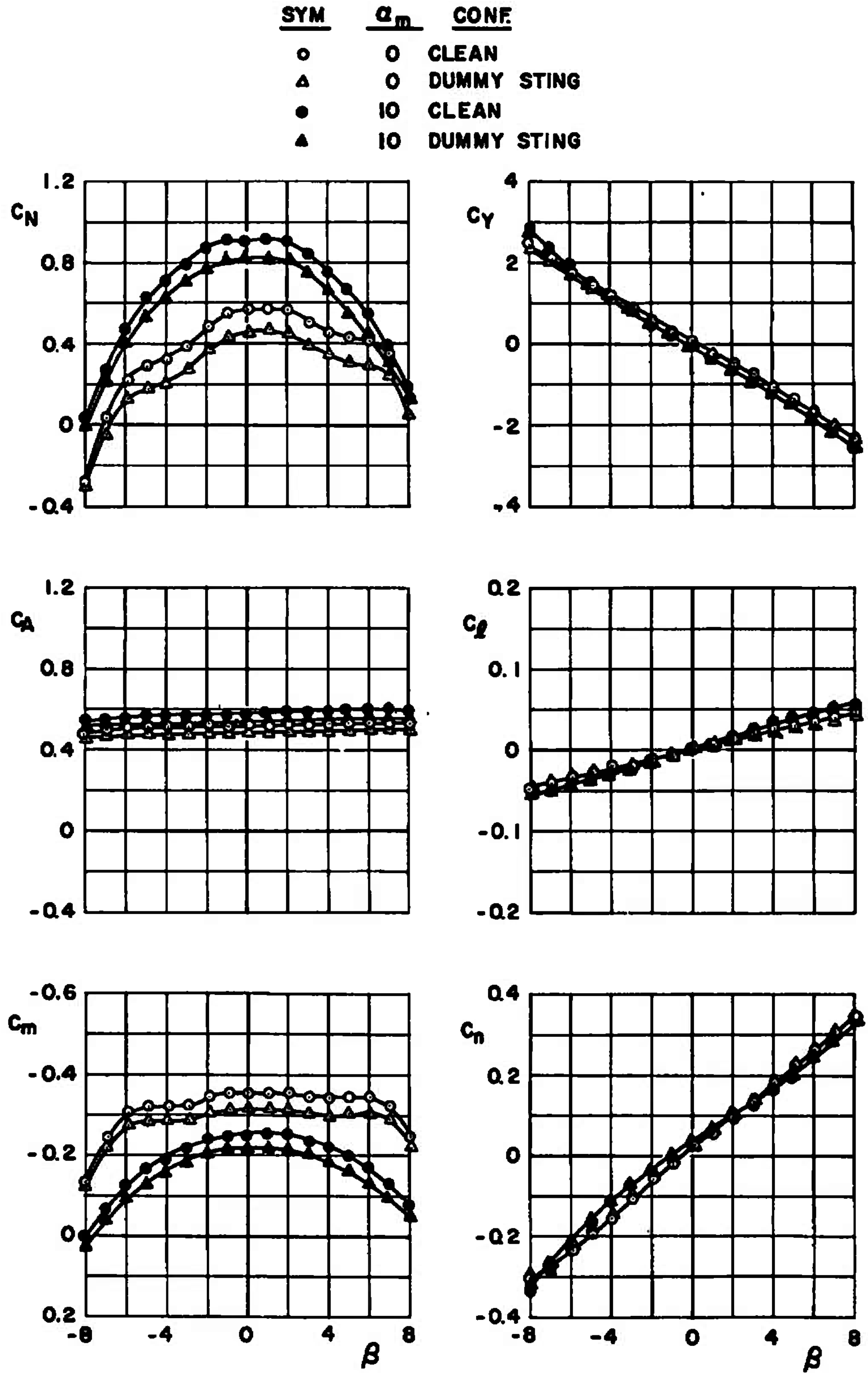


a. M_∞ = 0.50

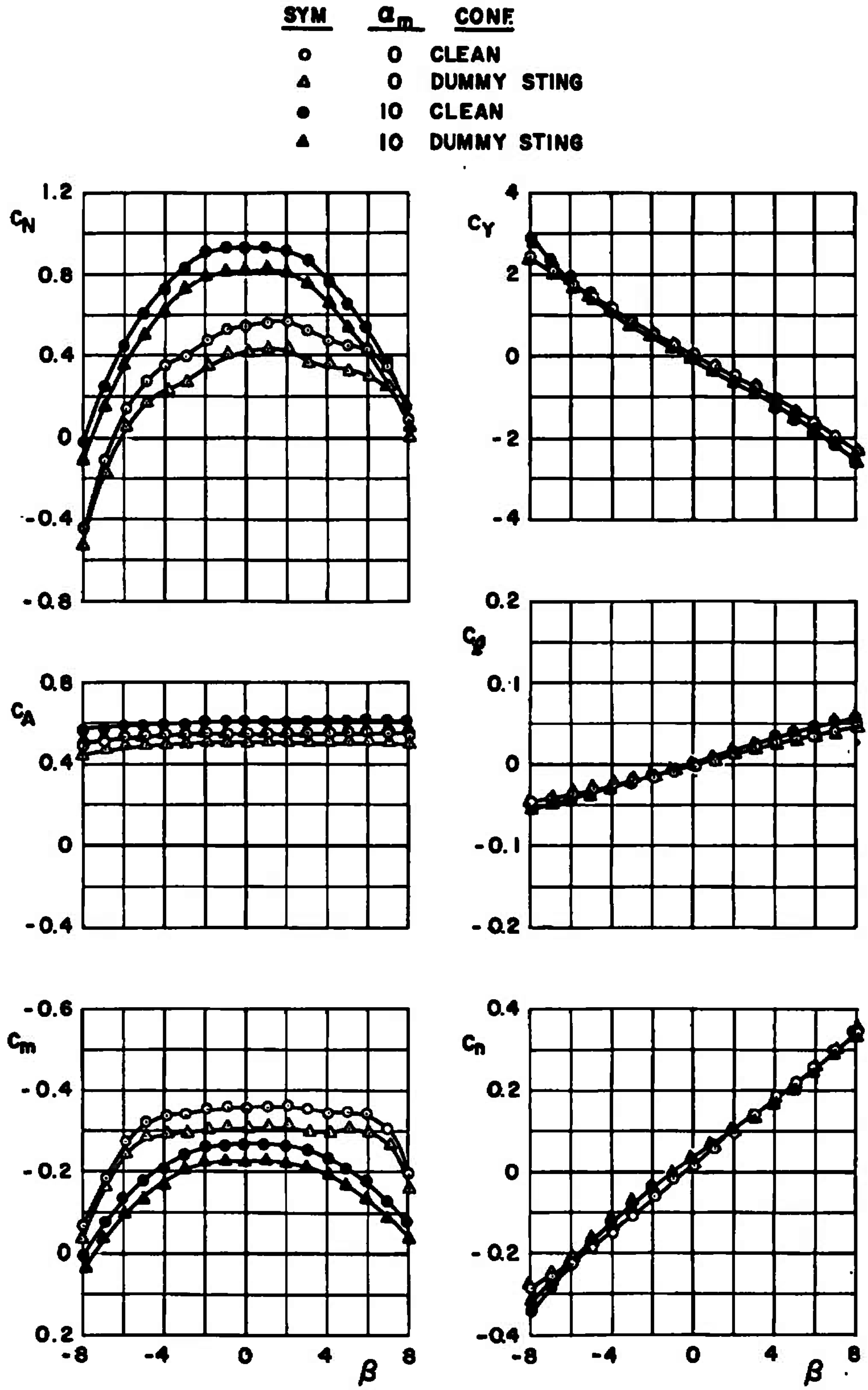
Fig. 9 SAGMI Aerodynamic Coefficients as a Function of Angle of Sideslip, α_m = 0 and 10 deg



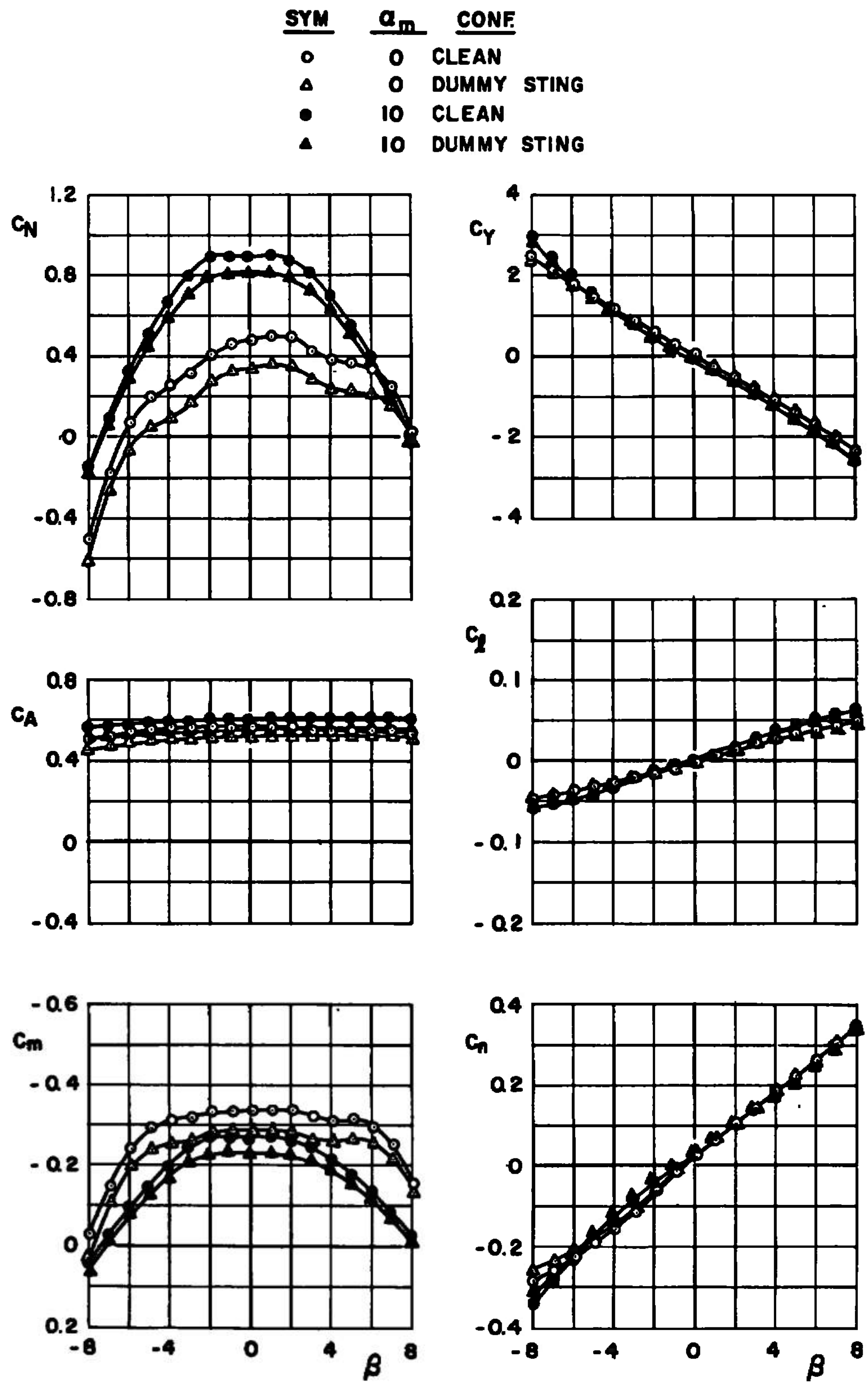
b. $M_\infty = 0.70$
Fig. 9 Continued



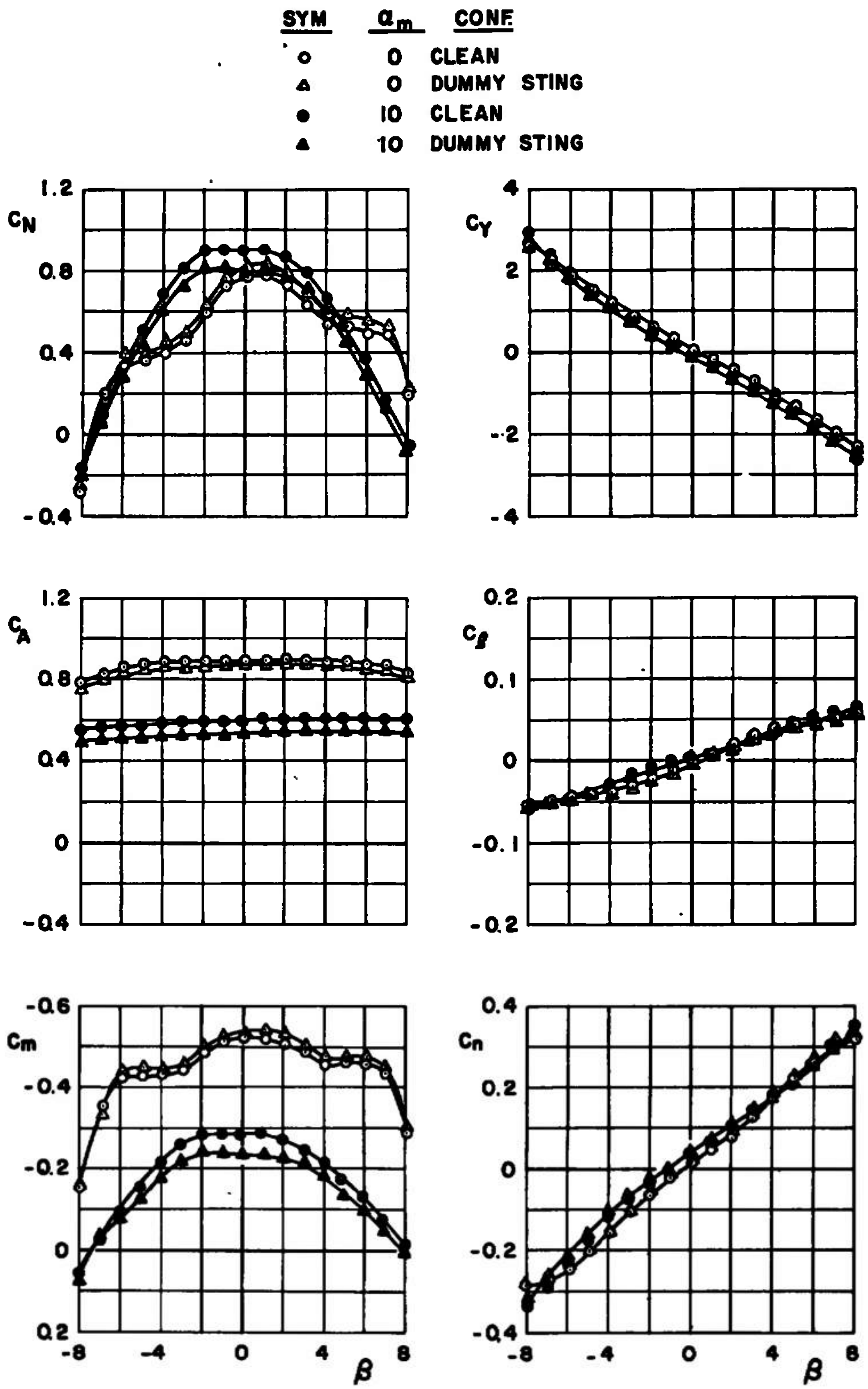
c. $M_\infty = 0.80$
Fig. 9 Continued



d. $M_\infty = 0.90$
Fig. 9 Continued

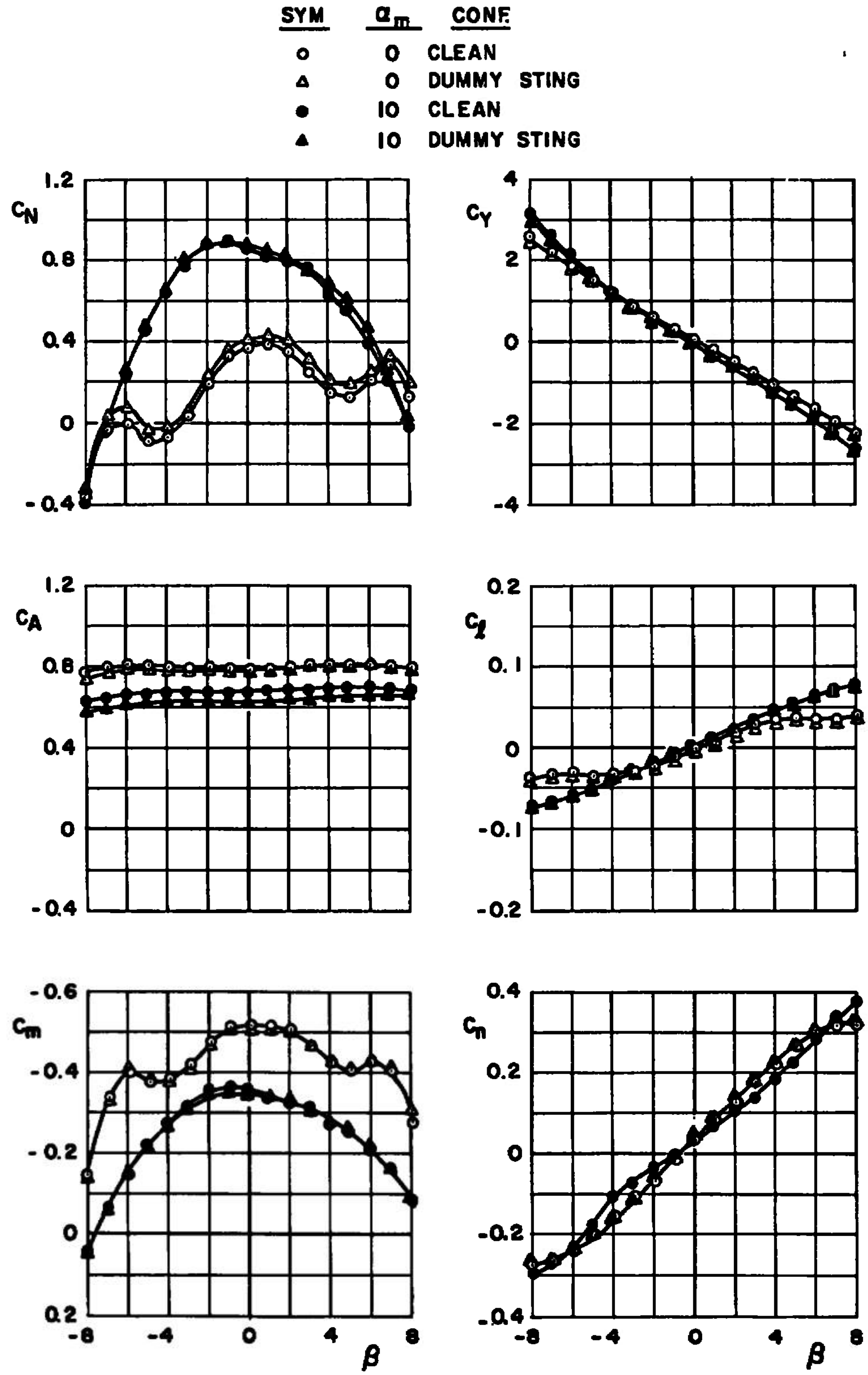


e. $M_\infty = 0.95$
Fig. 9 Continued

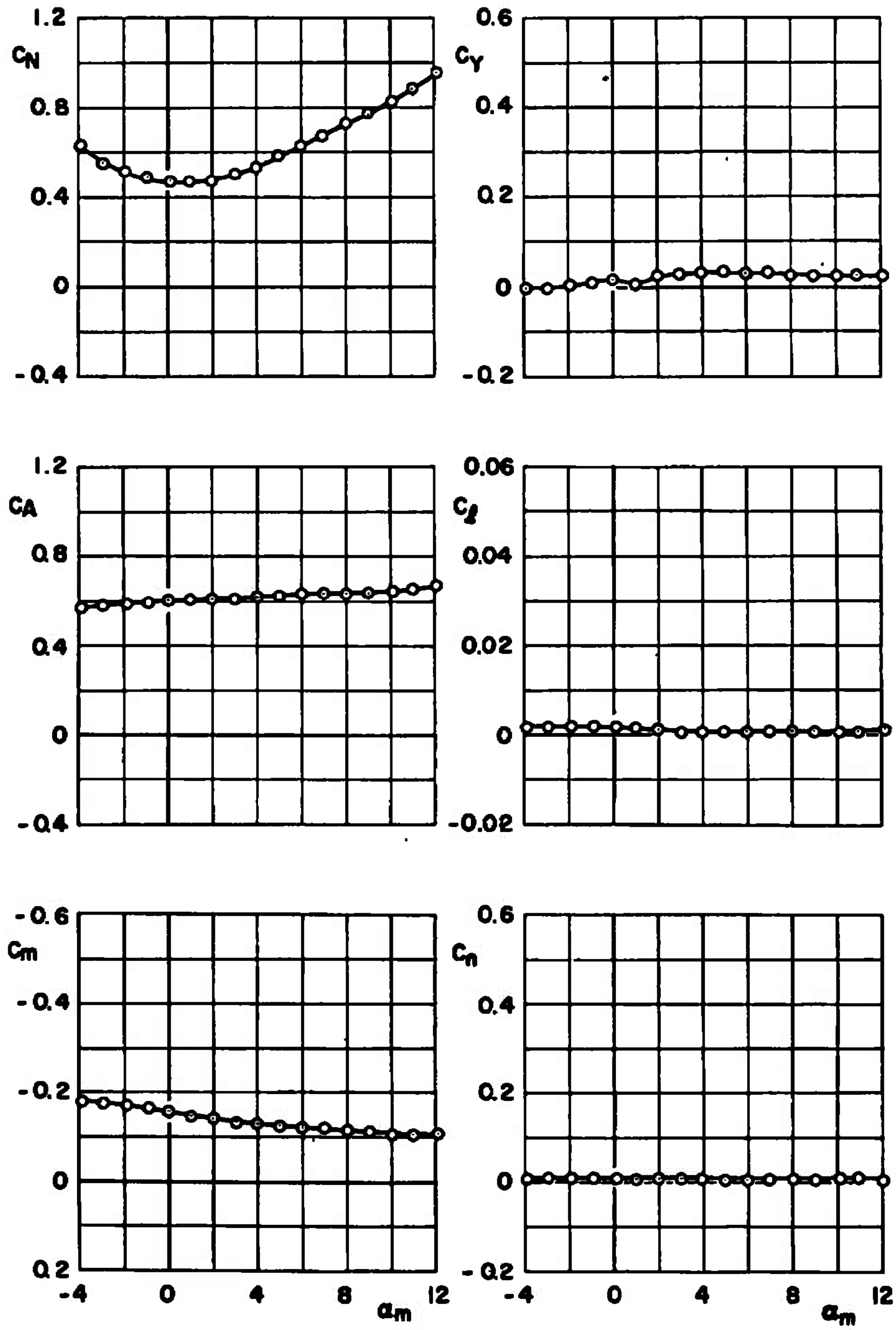


f. $M_\infty = 1.05$

Fig. 9 Continued

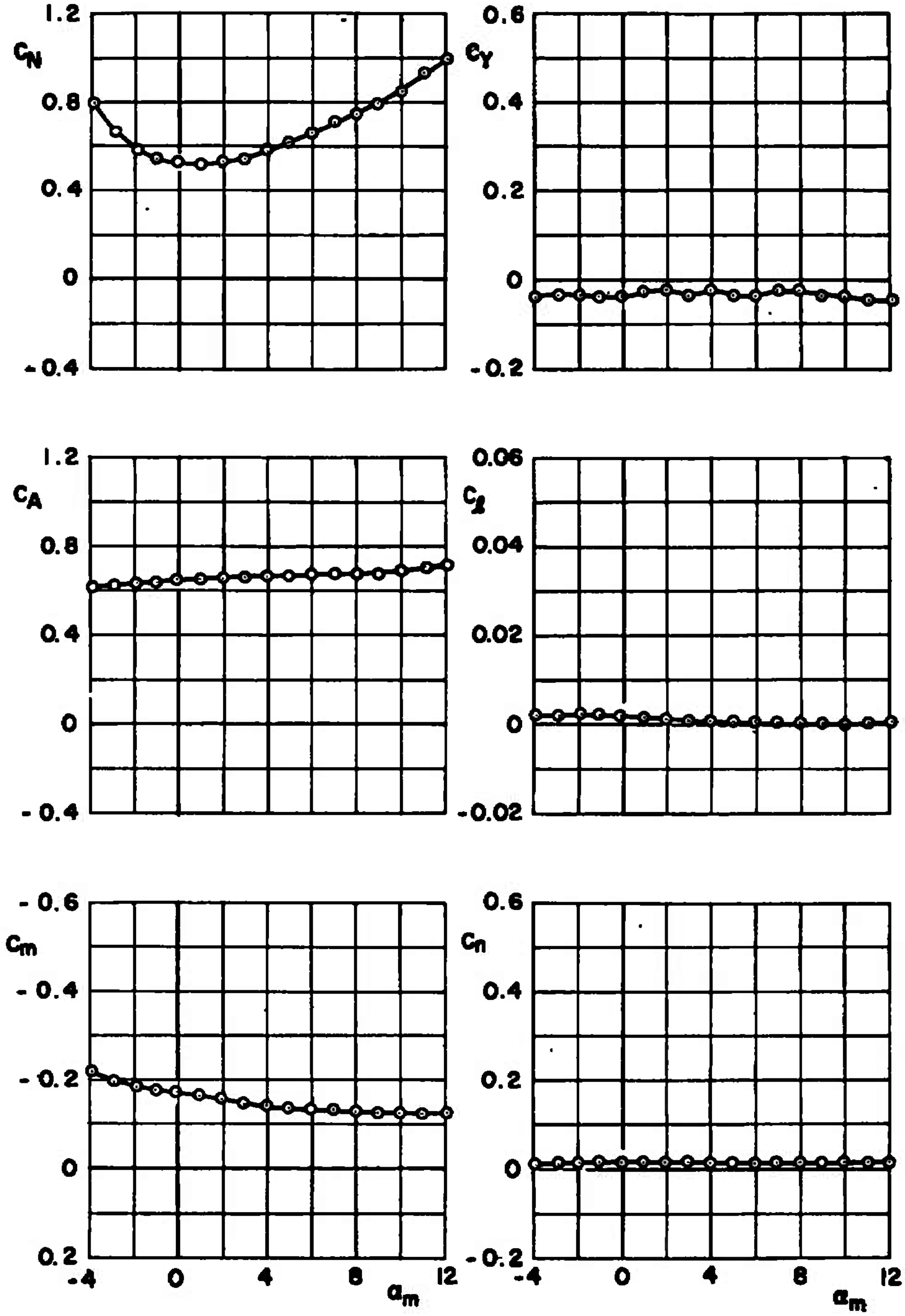


g. M_∞ = 1.20
Fig. 9 Concluded

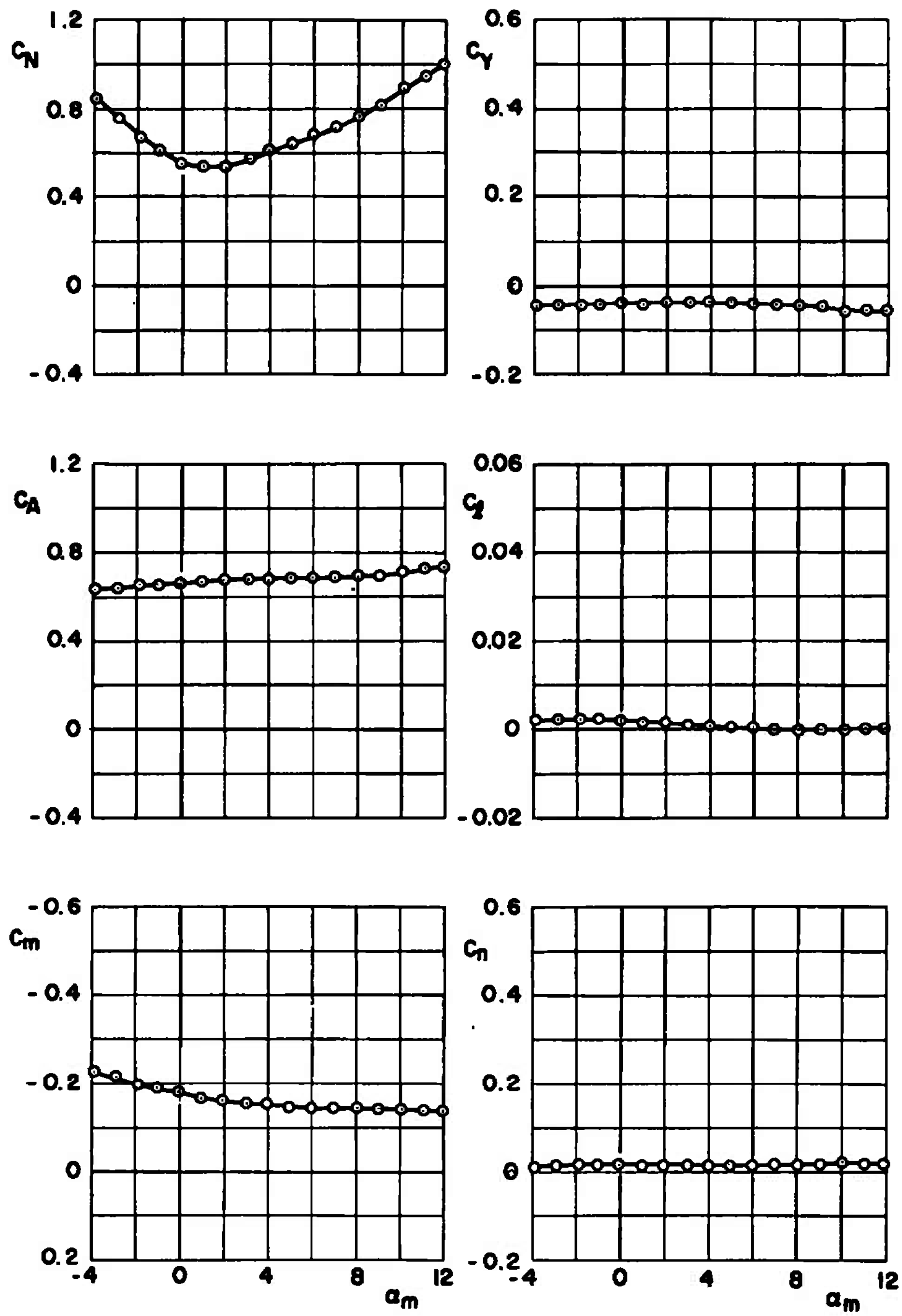


a. $M_\infty = 0.50$

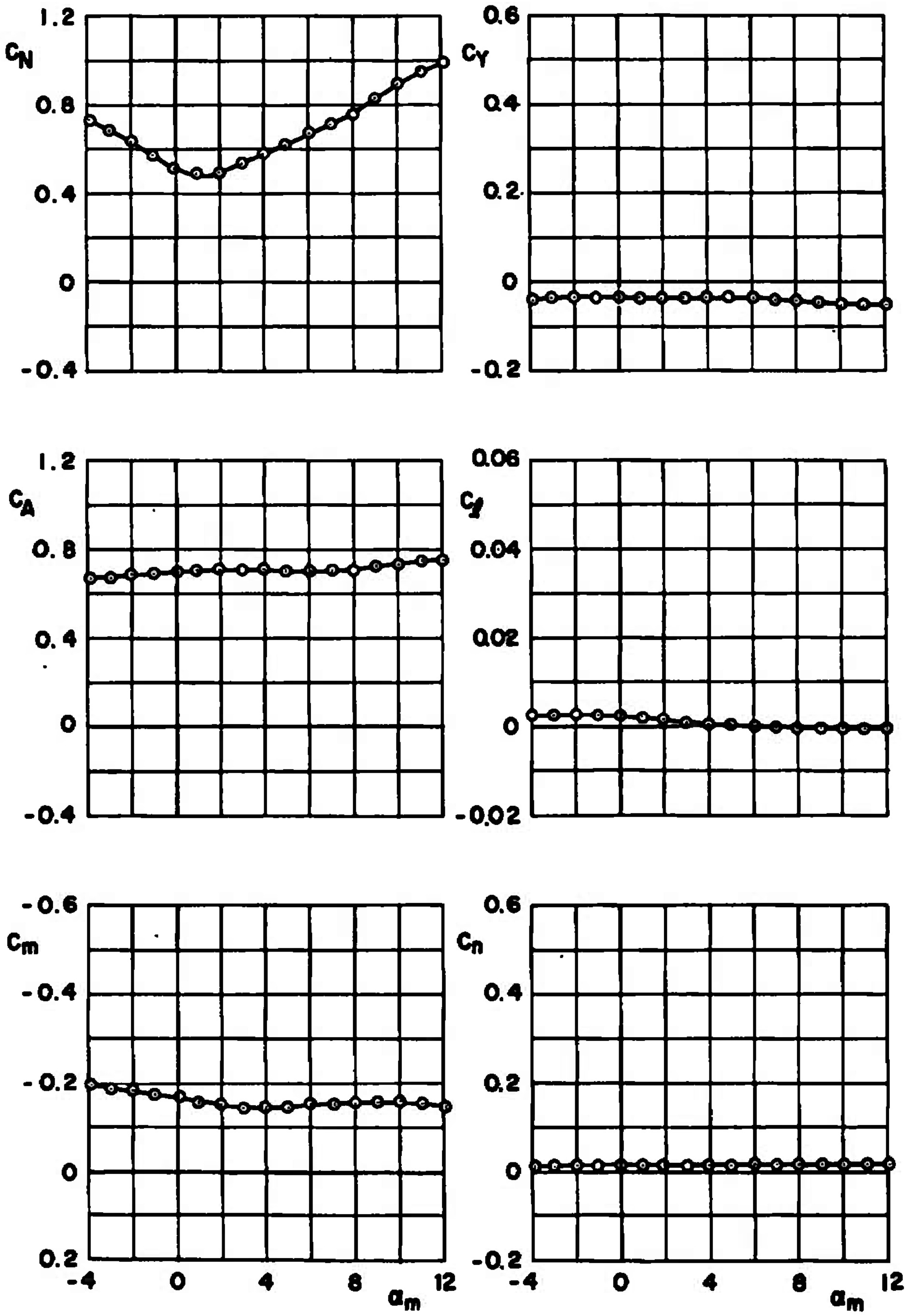
Fig. 10 HAST Aerodynamic Coefficients as a Function of Angle of Attack, $\beta = 0$



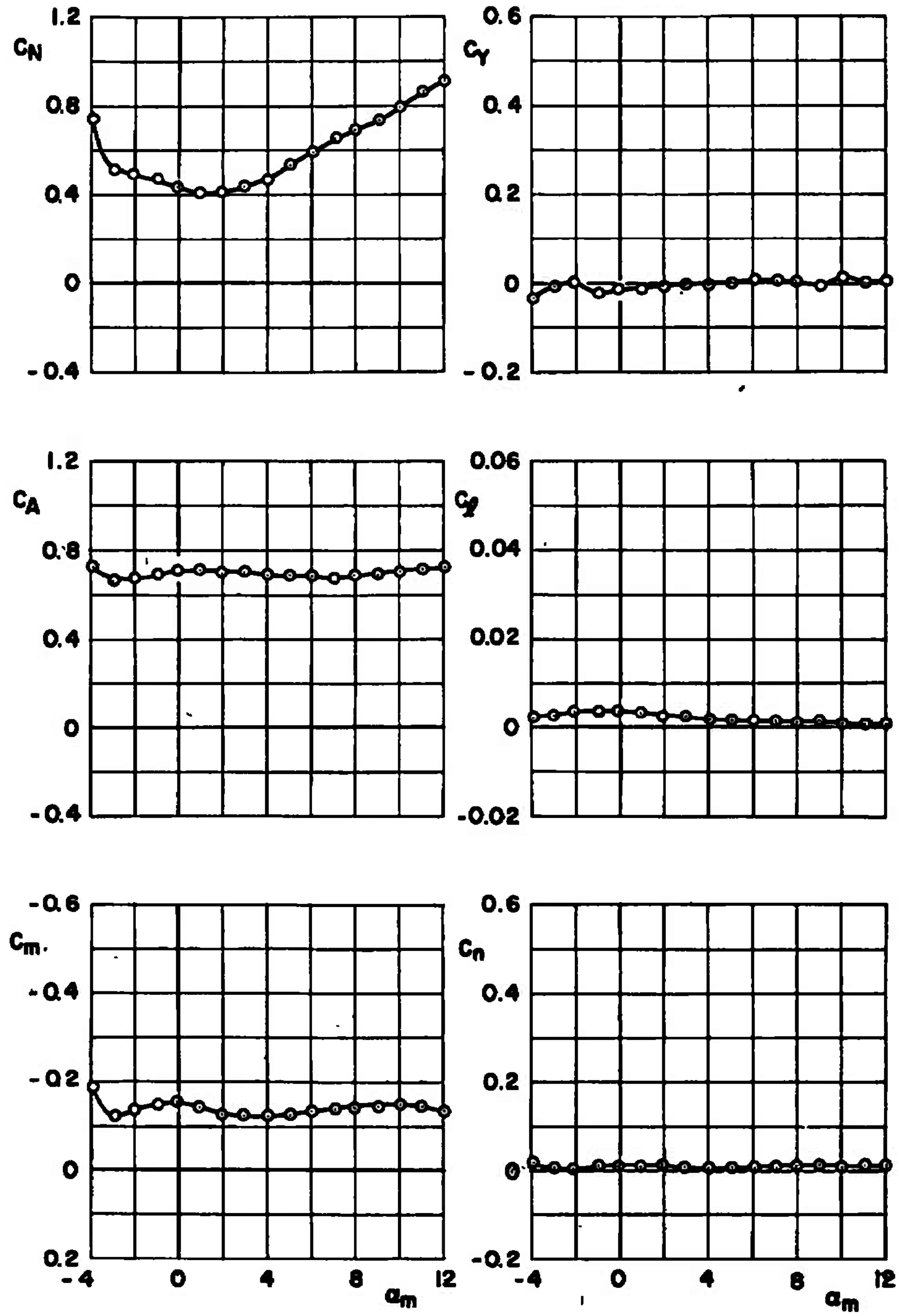
b. $M_\infty = 0.70$
Fig. 10 Continued



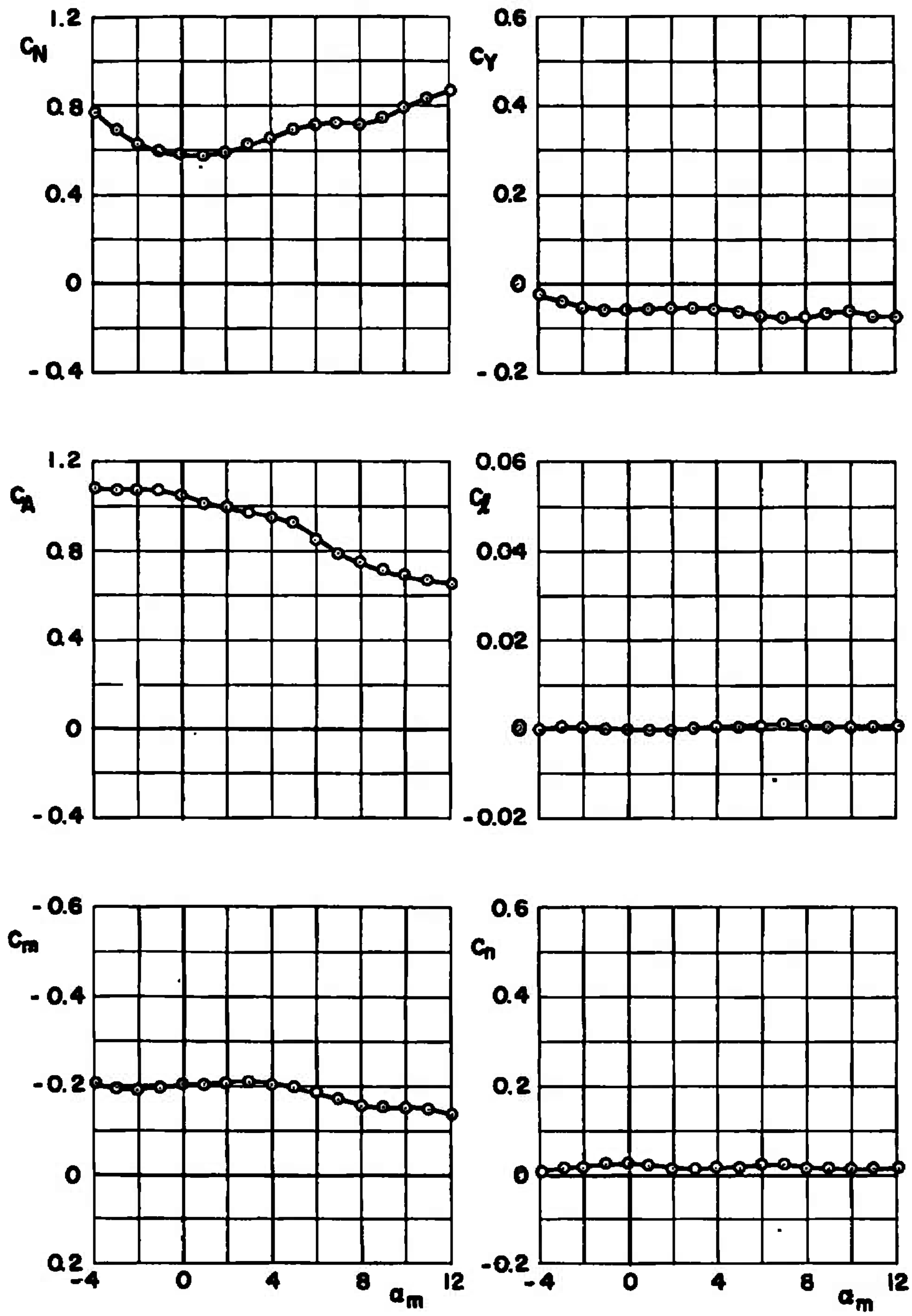
c. $M_\infty = 0.80$
Fig. 10 Continued



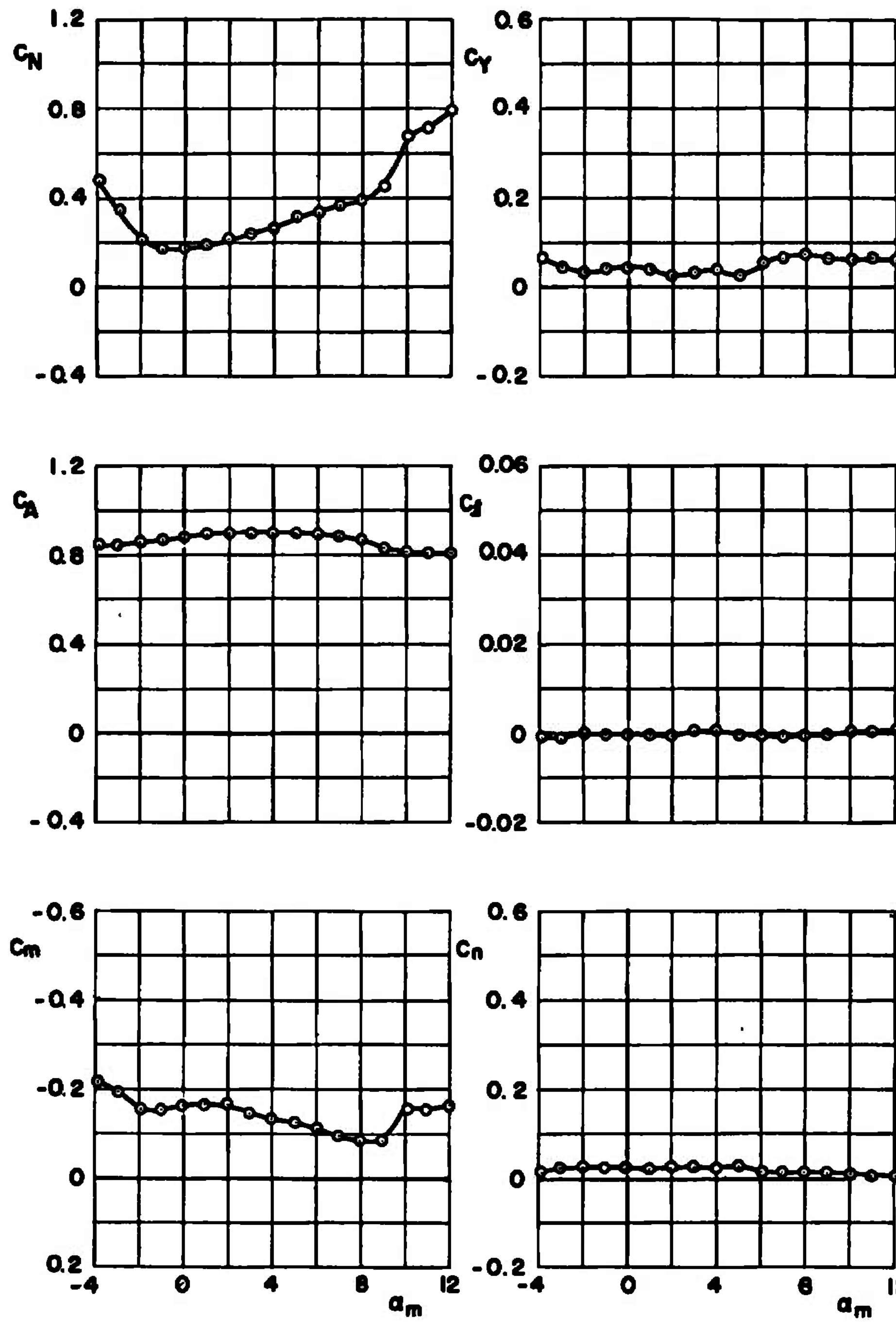
d. $M_\infty = 0.90$
Fig. 10 Continued



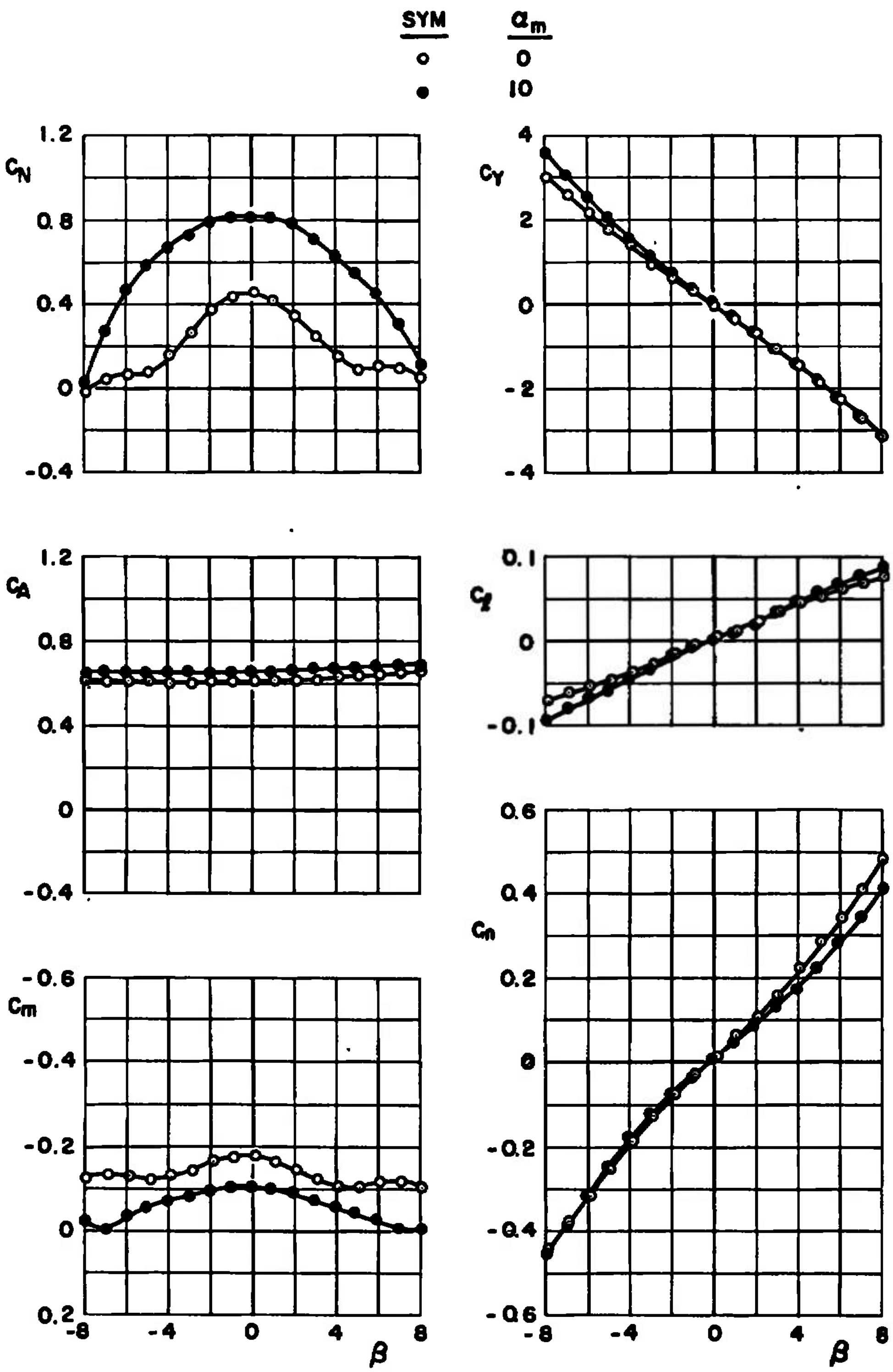
e. $M_\infty = 0.95$
Fig. 10 Continued



f. $M_\infty = 1.05$.
Fig. 10 Continued

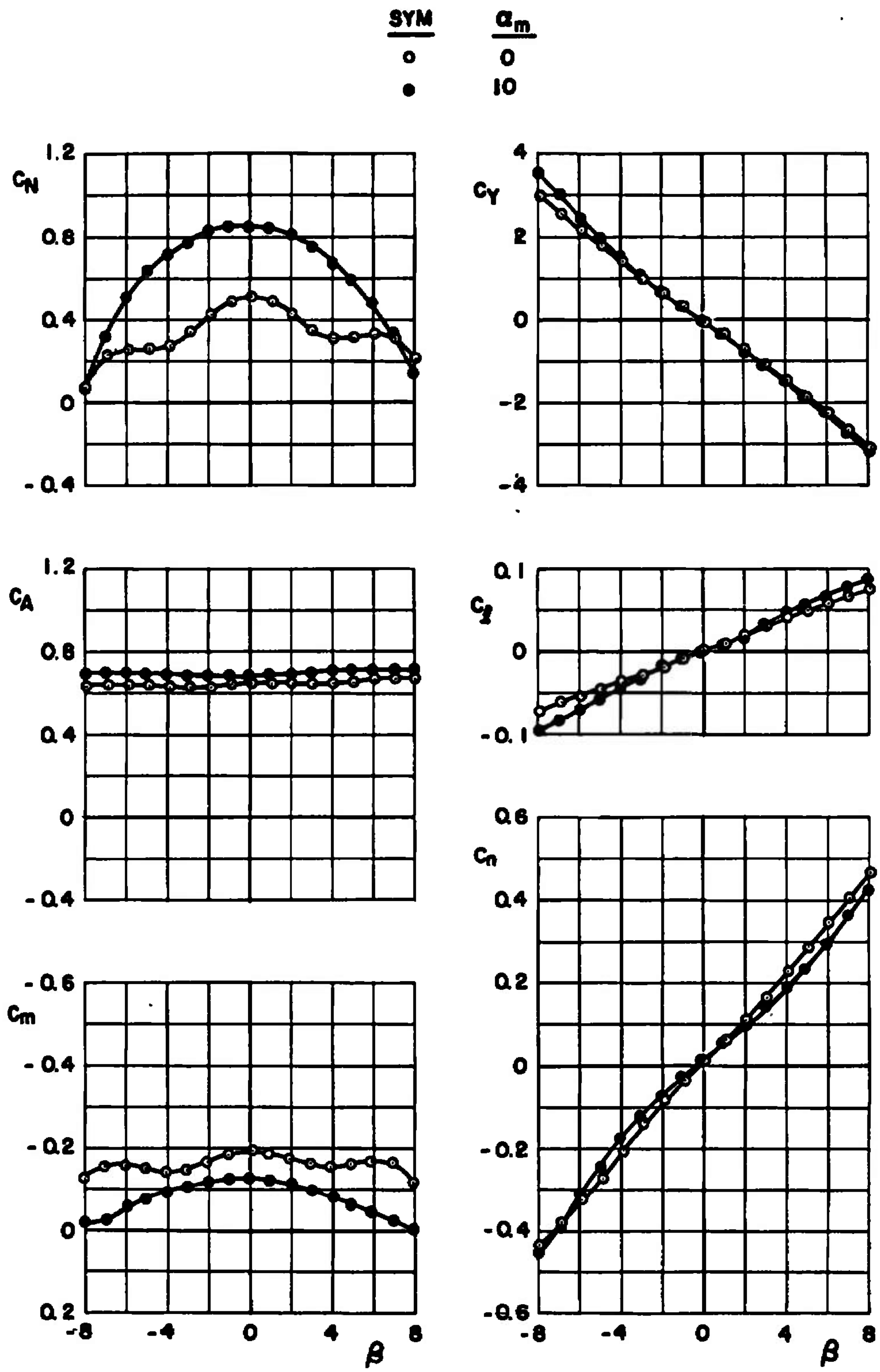


g. $M_\infty = 1.20$
Fig. 10 Concluded

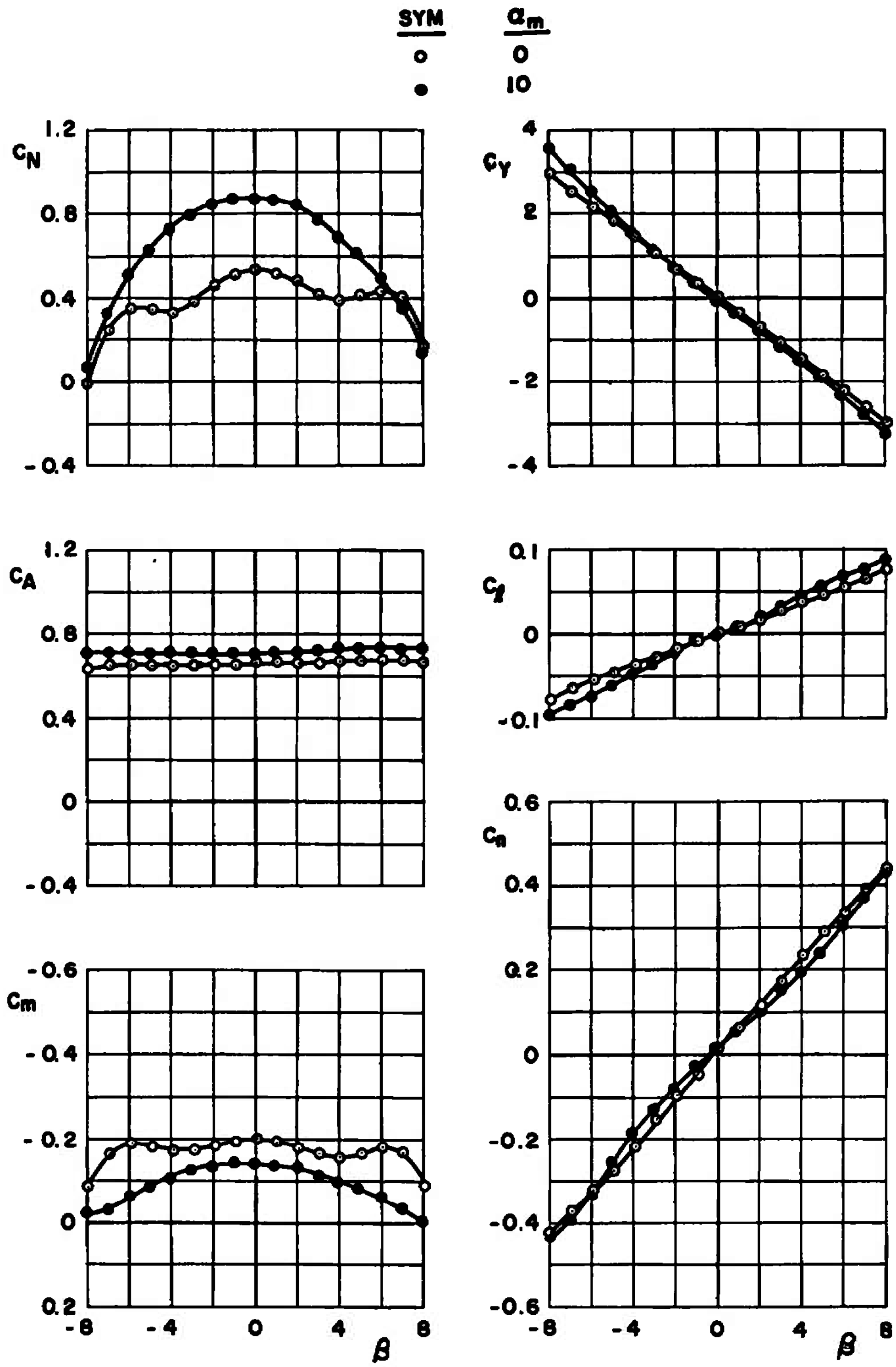


a. M_∞ = 0.50

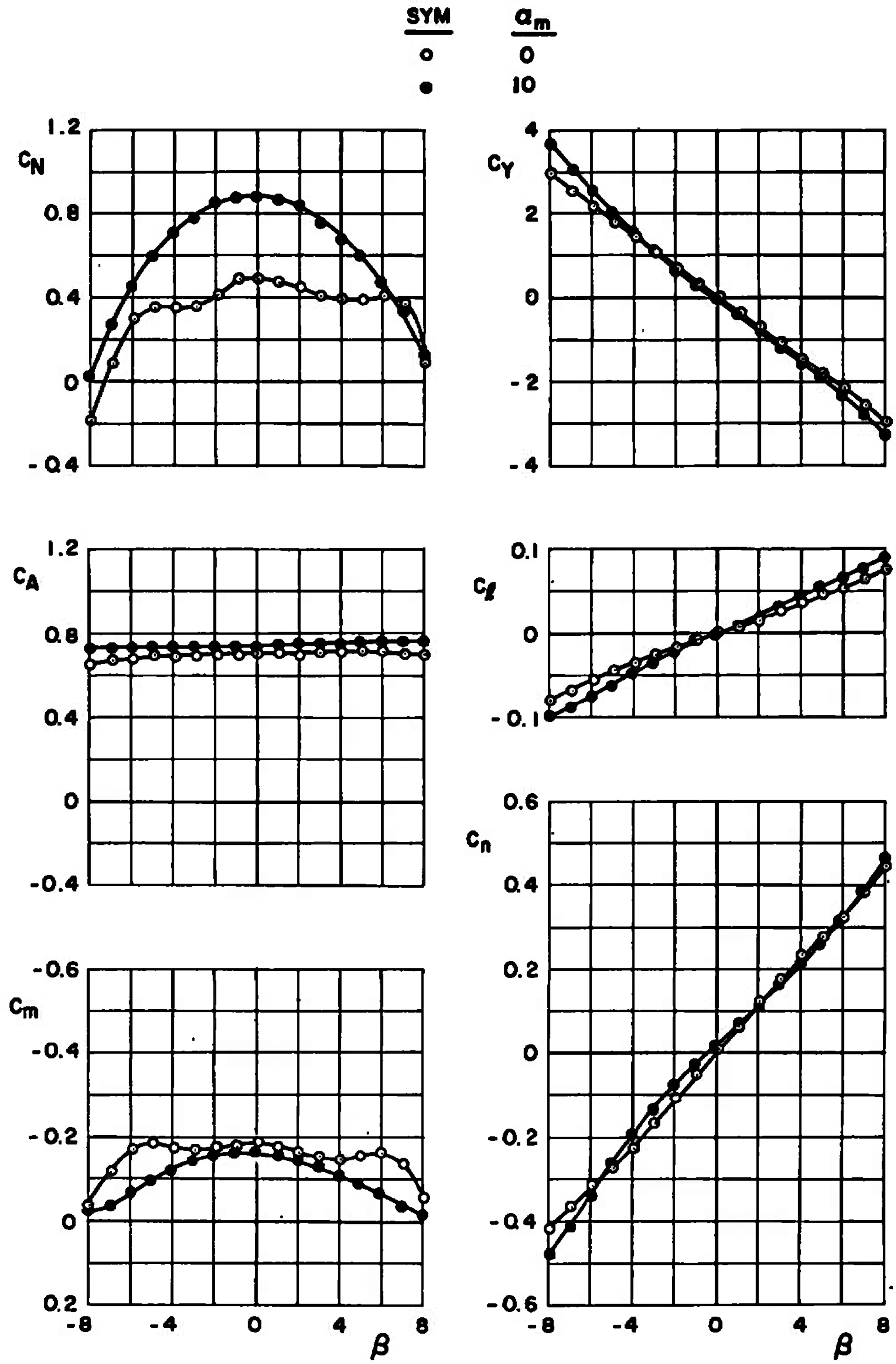
Fig. 11 HAST Aerodynamic Coefficients as a Function of Angle of Sideslip, α_m = 0 and 10 deg



b. $M_\infty = 0.70$
Fig. 11 Continued

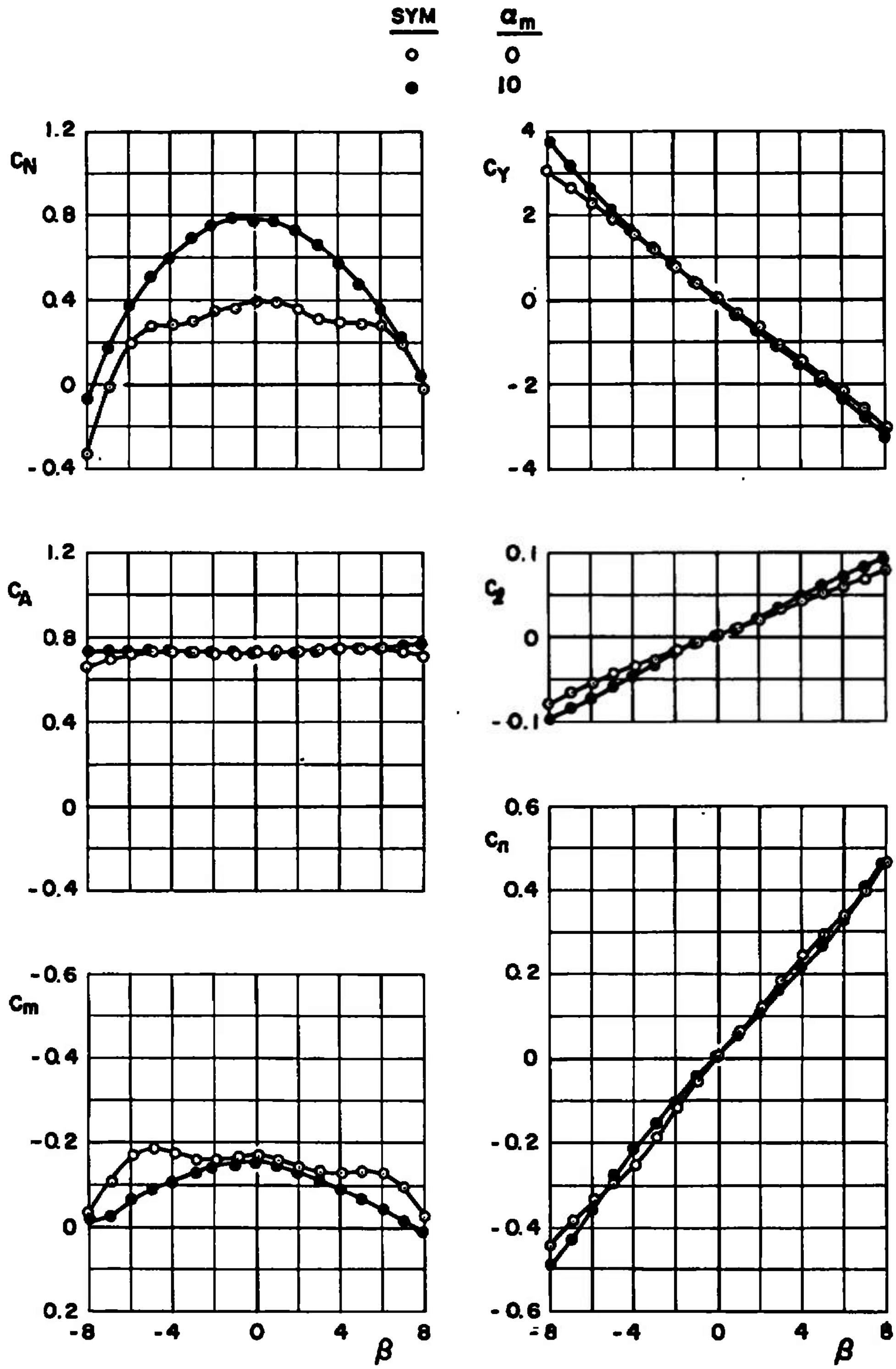


c. $M_\infty = 0.80$
Fig. 11 Continued

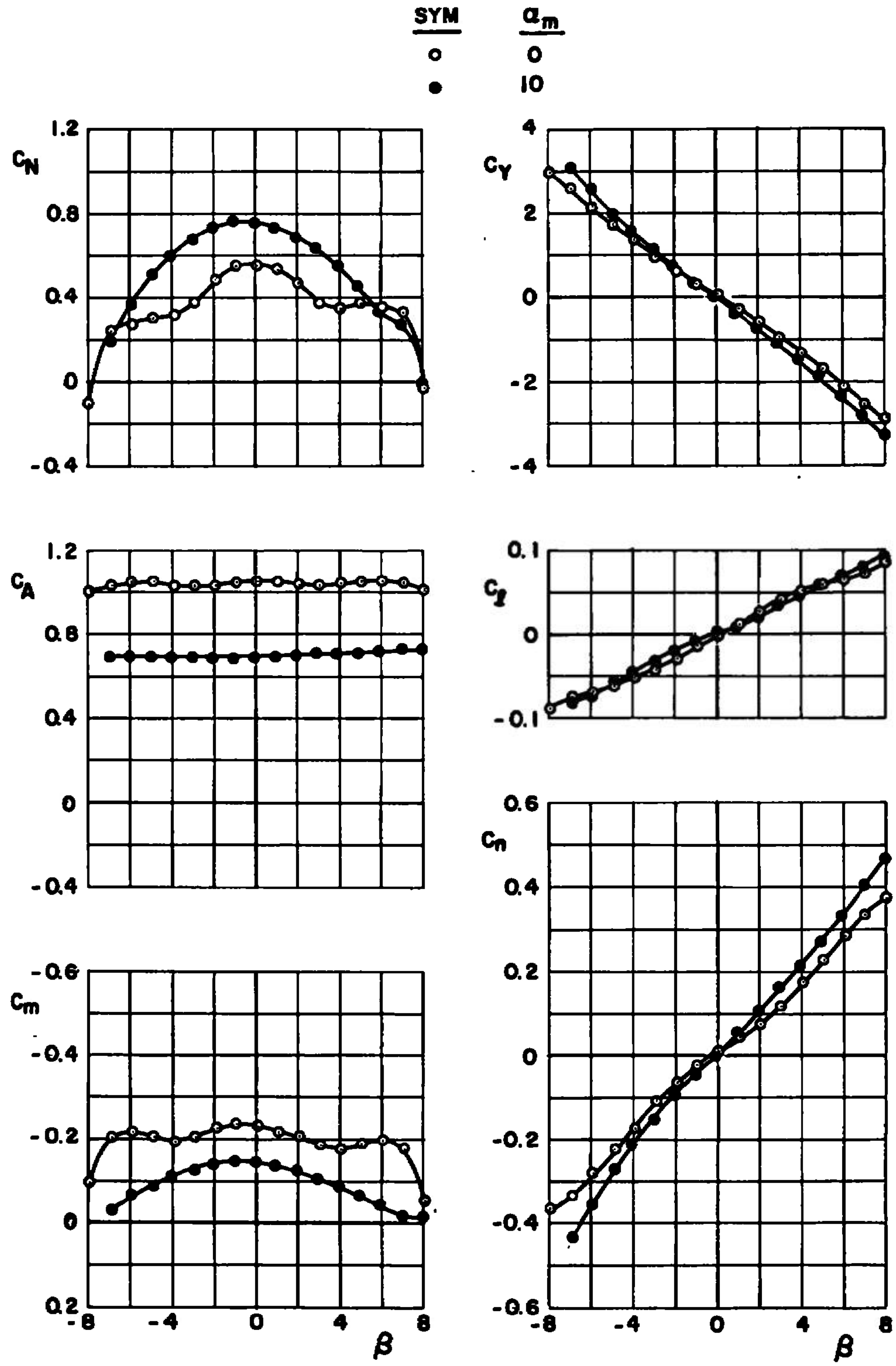


d. M_∞ = 0.90

Fig. 11 Continued

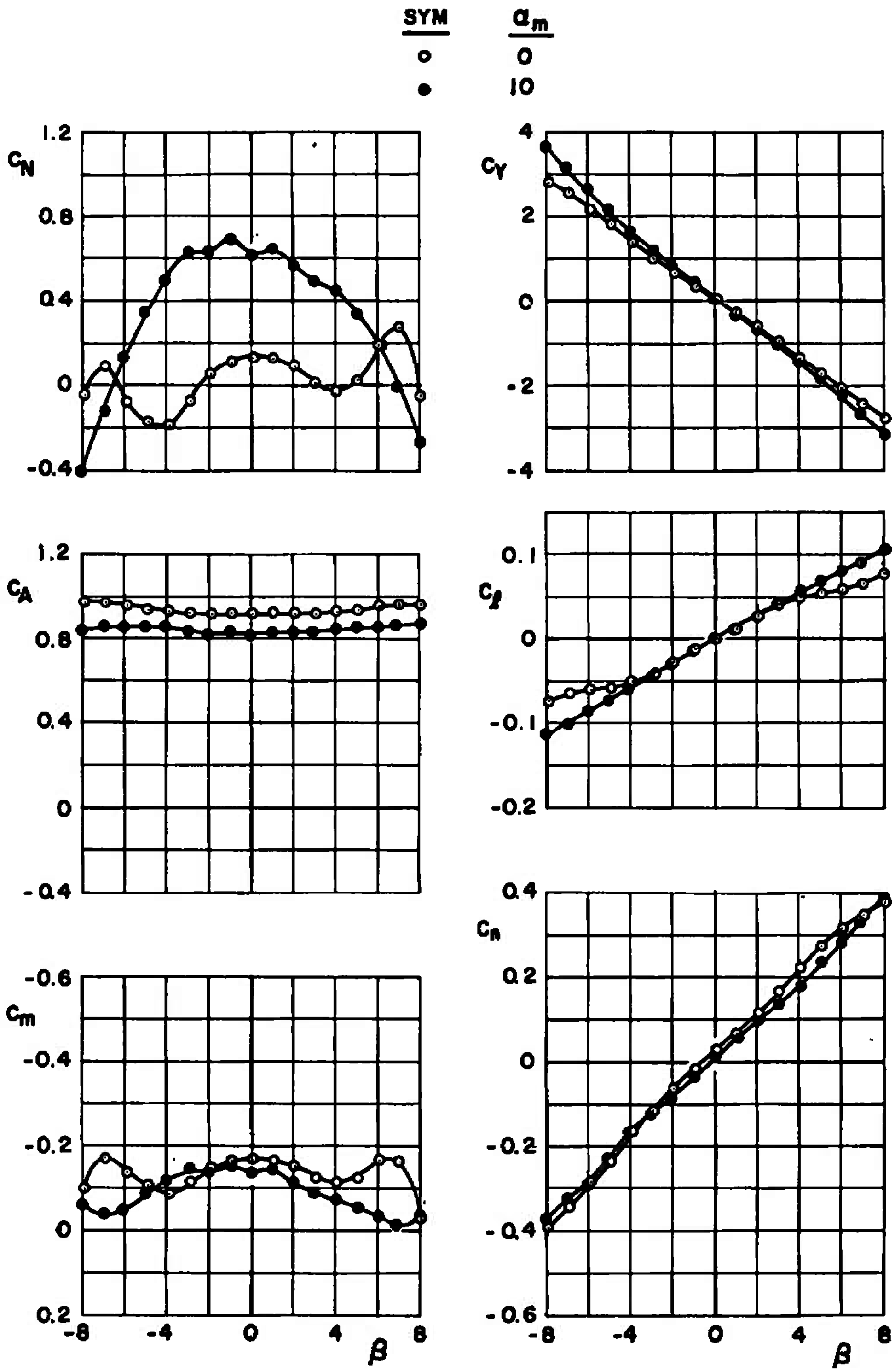


e. $M_\infty = 0.95$
Fig. 11 Continued



f. $M_\infty = 1.05$

Fig. 11 Continued



g. $M_\infty = 1.20$
Fig. 11 Concluded

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4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

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13. ABSTRACT

A wind tunnel investigation was conducted to determine the airloads on the SAGMI and HAST vehicles at the F-4C centerline carriage position. In the process of obtaining these loads, a limited amount of sting interference data on the SAGMI vehicle was obtained. Force and moment data were recorded at Mach numbers from 0.50 to 1.20 for angles of attack from -4 to 12 deg and angles of sideslip from -8 to 8 deg. Test results revealed that normal-force airloads experienced on the SAGMI and HAST vehicles while in the F-4C centerline carriage position at large angles of attack (8 to 12 deg) were orders of magnitude smaller than free-stream loads obtained on similarly shaped bodies. The addition of a dummy sting support at the base of the SAGMI vehicle resulted in a decrease in both normal-force and axial-force coefficients, with an increase in pitching-moment coefficient, at all subsonic test conditions.

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external stores						
aerodynamic forces						
airloads						
transonic wind tunnels						

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